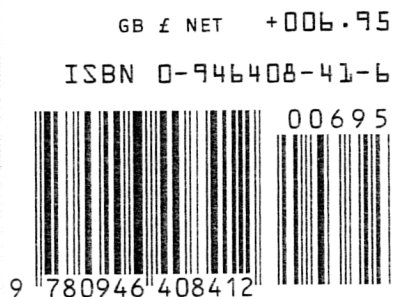


Artificial Intelligence on the Sinclair QL introduces the concepts involved in AI. The book shows you how to implement AI routines on your QL and turn it into an intelligent machine which can hold a conversation with you, give you rational advice, learn from you and even teach you.

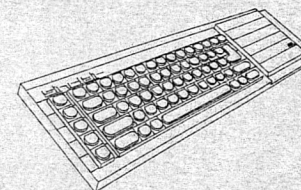
The book explains AI from first principles and assumes no previous knowledge of the subject. All the important aspects of AI are covered and are fully illustrated with example programs. In addition to covering programming in SuperBasic the book explains how to implement 'intelligent' routines for the QL Archive database program.

Artificial Intelligence is an increasingly important area which will have profound effects on all our lives in the next few decades. This book will give you an appreciation of the possibilities and problems which AI brings.

Keith and Steven Brain are a father and son team and have already published the best-selling Dragon 32 Games Master, Advanced Sound and Graphics for the Dragon computer and Artificial Intelligence on the Spectrum. They are both regular contributors to Popular Computing Weekly.

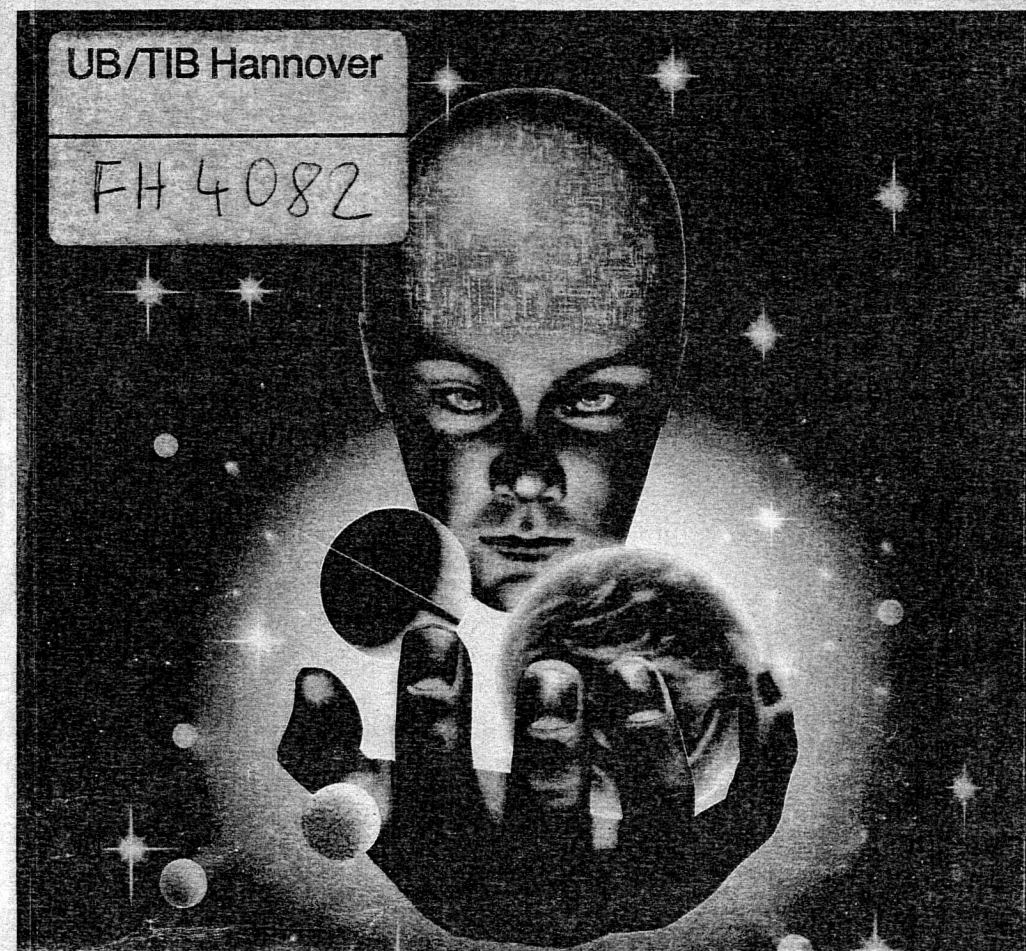


# Artificial Intelligence on the Sinclair QL



Make your micro think

**Keith and Steven Brain**



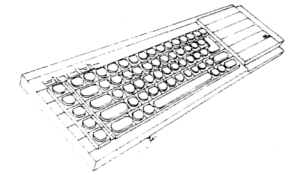
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# Artificial Intelligence on the Sinclair QL

Make your micro think



Keith and Steven Brain



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### CHAPTER 2

#### Just Following Orders

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### CHAPTER 3

#### Understanding Natural Language

Dealing with sentences — subjects, objects, verbs, adjectives, adverbs — punctuation — a sliding search — partial matching — rearranging the wordstore array.

### CHAPTER 4

#### Making Reply

Getting more sensible replies — checking many words — making logical decisions before replying — picking the appropriate reply — alternative subjects — putting the subject in context — inserting the subject in the sentence — problems with objects — changing tense.

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#### Expert Systems

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Letting the computer work out its own rules for two objects — expanding the system — automatic digestion.



## CHAPTER 7

### Fuzzy Matching

Recovering information from the human mind — soundex coding — a program for converting names — retrieving information.

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### Recognising Shapes

Simulating the action of a light sensor — looking at a smaller number of features of the pattern.

## CHAPTER 9

### An Intelligent Teacher

Questions and answers — keeping a score — shifting the emphasis of questions to areas of difficulty — making questions easier or harder.

## CHAPTER 10

### Of Mice and Men

Setting the scene — making the maze — finding the route — reaching the centre — deciding where to move to — coping with corners — reducing the amount of checking — random selection at junctions — backtracking — finding new routes — speeding up.

## CHAPTER 11

### Intelligent Use of Archive

Extracting the required information correctly — finding a match — searching specifically — selecting records — putting things in order — using PROCedures — a more friendly (inter)face.

## CHAPTER 12

### A Naturally Expert Salesman

Combining processing natural language with an expert system — making conversation with the computer — making decisions — the Computer Salesman.

## Program Notes

The order of the X and Y coordinates in the 'AT' command vary with the version of the ROM. If the screen organisation looks wrong, then simply reverse the two parameters following AT.

## Introduction

Artificial intelligence is undoubtedly an increasingly important area in computer development and one which will have profound effects on all our lives in the next few decades. The main aim of this book is to introduce the unenlightened reader to some of the concepts involved in artificial intelligence and to show them how to develop 'intelligent' routines on the QL which they can then incorporate into their own particular programs. Only a superficial knowledge of programming is assumed and the book works from first principles as we believe that this is essential if you are really to understand the problems involved in simulating intelligence, and how to set about overcoming them.

The basic format of the book is that ideas are taken and suitable routines built up step by step, exploring and comparing alternative possibilities wherever possible. Rather than simply giving you a series of completed programs, we encourage you to experiment with different approaches to let you see the results of variations in technique for yourself. Detailed flowcharts of most of the routines are included.

Although the main emphasis is placed on the AI aspects of the routines, we have taken the opportunity to exploit many of the advantages of SuperBASIC, such as PROCedures, FuNctions, and Windows.

You may notice that in places certain lines are strictly redundant, but these have been deliberately included in the interests of clarity of program flow. As far as possible, retyping of lines is strenuously avoided but modification of routines is commonplace. Certain defined PROCedures are common to several chapters and we remind you that these can be SAVED separately to microdrive and then transferred into the different programs with the MERGE command.

All listings in the book are formatted so that they clearly show nesting and program flow, and so they do not appear exactly as they will on the screen display. In most cases spaces and brackets have been used liberally to make listings easier to read but be warned that some spaces and brackets are essential so do not be tempted to remove them all.

All routines have been rigorously tested and the listings have been checked very thoroughly so we hope that you will not find any bugs. It is a sad fact of life that most bugs arise as a result of 'tryping mitsakes' by the user. Semicolons and commas may look insignificant but their absence can have profound effects!

Artificial intelligence is increasing in importance every day and we hope that this book will give you a useful insight into the area. Who knows — if you really work at the subject you might be able to persuade your machine to read our next book for itself!

Once again thanks are due to Liz who has managed to resist the temptation to throw out 'all that rubbish' and redecorate the room.

Keith and Steven Brain  
Groeswen, July 1984

## CHAPTER 1

# Artificial Intelligence

### **Fantasy**

For generations science fiction writers have envisaged the development of intelligent machines which could carry out many of the functions of man himself (or even surpass him in some areas), and the public image of artificial intelligence has undoubtedly been coloured by these images.

The most common view of a robot is that it is an intelligent machine of generally anthropomorphic (human) form which is capable of independently carrying out instructions which are given to it in only a very general manner. Of course, most people have ingrained Luddite tendencies when it comes to technology so in the early stories these robots tended to have a very bad press, being cast in the traditional role of the 'bad guys' but with near-invincibility and lack of conscience built in.

The far-sighted Isaac Asimov wove a lengthy series of stories around his concept of 'positronic robots' and was probably the first author really to get to grips with the realities of the situation. He laid down his famous 'Three Laws of Robotics' which specified the basic ground rules which must be built into any machine which is capable of independent action — but it is interesting to note that he could not see the time when the human race would accept the presence of such robots on the earth itself. 'Star Wars' introduced the specialised robots R2D2 and C3PO, but we feel that many of their design features were a little strange: perhaps there is a 'Interplanetary Union of Robots' and a demarcation dispute prevented direct communication between humans and R2D2.

Of course intelligent computers also appear in boxes without arms and legs, although flashing lights seem obligatory. Input/output must obviously be vocal but the old metallic voice has clearly gone out of fashion in favour of some more definite personality. If all the boxes look the same then this must be a good idea, but please don't make them all sound like Sergeant-Major Zero from 'Terrahawks'!

Michael Knight's KITT sounds like a reasonable sort of machine to converse with, and it is certainly preferable to the oily SLAVE and obnoxious ORAC from 'Blake's Seven'. ORAC seemed to pack an enormous amount of scorn into that little perspex box but other writers have appreciated the difficulties which may be produced if you make the personality of the machine too close to that of man himself. In Arthur C.



Clarke's '2001: A Space Odyssey' the ultimately-intelligent computer HAL eventually had a nervous breakdown when he faced too many responsibilities. In 'The Restaurant At The End of The Universe' the value of the 'Sirius Cybernetics Corporation Happy Vertical People Transporter' was reduced significantly when it refused to go up as it could see into the future and realised that if it did so it was likely to get zapped, and the 'Nutri-Matic Drinks Synthesiser' was obviously designed by British Rail Catering as it always produced a drink that was 'almost, but not quite, entirely unlike tea'. More recently the rather flashy holographic figure of 'Automan' has demonstrated some quite amazing capabilities in his fight against crime, although there do seem to be some major omissions in his programming with regard to dealings with women.

More worrying themes have also recently appeared. The most significant feature of 'Wargames' was not that someone tapped into JOSHUA (the US Defence Computer) but that once the machine started playing thermonuclear war it wouldn't stop until someone had won the game. In 'The Forbin Project' the US and Russian computers got together and decided that humans are pretty irrelevant anyway.

## Reality

The definition and recognition of machine intelligence is the subject of fast and furious debate amongst the experts in the subject. The most generally accepted definition is that first proposed by Alan Turing way back in the late 1940s when computers were the size of houses and even rarer than a slide-rule is today. Rather than trying to lay down a series of criteria which must be satisfied, he took a much broader view of the problem. He reasoned that most human beings accept that most other human beings are intelligent and that therefore if someone cannot determine whether they are dealing with another man or woman, or only a computer, then they must accept that the machine is intelligent. This forms the basis of the famous 'Turing Test' in which an operator has to hold a two-way conversation with another entity via a keyboard and try to get the other party to reveal whether it is actually a machine or just another human being — very awkward!

Many fictional stories circulate about this test, but our favourite is the one where a job applicant is set down in front of a keyboard and left to carry on by himself. Of course he realises the importance of this test to his career prospects and so he struggles valiantly to find the secret, apparently without success. However, after some time the interviewer returns, shakes him by the hand, and congratulates him with the words: 'Well done, old man, the machine couldn't tell if you were human so you are just what we need as one of Her Majesty's Tax Inspectors!'

Everyone has heard from the TV advertisements that the use of

computer-aided design techniques is now very common and that industrial robots are almost the sole inhabitants of car production lines (leading to the car window sticker which claims 'Designed by a computer, built by a robot, and driven by an idiot'). In fact most of these industrial robots are really of minimal intelligence as they simply follow a pre-defined pathway without making very much in the way of actual decisions. Even the impressive paint-spraying robot which faithfully follows the pattern it learns when a human operator manually moves its arm cannot learn to deal with a new object without further human intervention.

On the other hand the coming generation of robots have more sophisticated sensors and software which allow them to determine the shape, colour, and texture of objects, and to make more rational decisions. Anyone who has seen reports of the legendary 'Micromouse' contests where definitely non-furry electric vermin scurry independently and purposefully (?) to the centre of a maze will not be amazed by our faith in the future of the intelligent robot, although there seems little point in giving it two arms and two legs.

Another important area where artificial intelligence is being currently exploited is in the field of expert systems, many of which can do as well (or even better) than human experts, especially if you are thinking about weather forecasting. These systems can be experts on any number of things but, in particular, they are of increasing importance in medical diagnosis and treatment — although the medical profession doesn't have to worry too much as there will always be a place for them since 'computers can't cuddle'.

A major barrier to wider use of computers is the ignorance and pigheadedness of the users, who will only as a last resort read the instructions, and expect the machine to be able to understand all their little peculiarities. Processing of 'natural language' is therefore a major growth area and the 'fifth generation' of computers will be much more user-friendly.

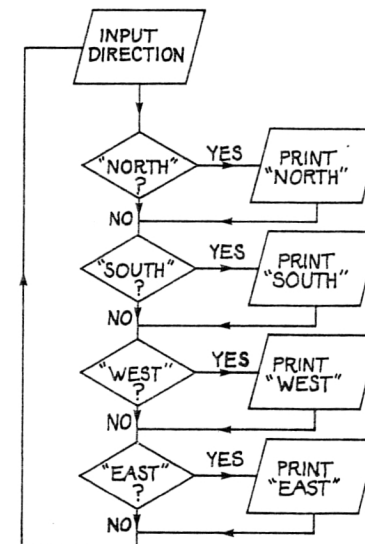
Most of the serious work on AI uses more suitable (but exotic) languages, such as LISP and PROLOG, but unfortunately these tend to be pretty unintelligible to the average user! The SuperBASIC routines which follow cannot be expected to give you the key to world domination, although they should give you a reasonable appreciation of the possibilities and problems which artificial intelligence brings. Like all specialists, the experts in AI have their own technical jargon with which to impress the ignorant natives. However, as this book is squarely aimed at the edification of Mr/Ms Average, we have deliberately chosen to avoid the use of such jargon wherever possible, as we feel that it tends to confuse rather than aid the novice!

## CHAPTER 2

### Just Following Orders

As your computer is actually totally unintelligent, you can really only converse with it at a relatively basic level, and in a formally structured way. We will demonstrate later how you can try to break down this 'language barrier', but let's make sure we can walk before we try to run. The first step is to have a series of preset orders to which there are fixed responses.

We will start by examining the problems involved in making the computer understand you giving it compass directions. At first sight the simplest way to program this appears to be to form a REPEAT loop which asks for an INPUT from the user and contains a separate IF-THEN line for each possibility (see **Flowchart 2.1**).



Flowchart 2.1: Giving Compass Directions.

We will use two PROCedures, which will be steadily refined as the chapter progresses. For the moment, START just clears the screen,

whilst WHICHWAY does the work of comparing your input with four key command words.

```

10 START
20 WHICHWAY

10000 DEFINE PROCEDURE START
10010 CLS
10990 END DEFINE START

11000 DEFINE PROCEDURE WHICHWAY
11010 REPEAT DIRECTION
11020 UNDER 0 : PRINT "\"DIRECTION?"
11030 INPUT IN$ : UNDER 1
11100 IF IN$="NORTH" THEN PRINT "NORTH"
11110 IF IN$="SOUTH" THEN PRINT "SOUTH"
11120 IF IN$="WEST" THEN PRINT "WEST"
11130 IF IN$="EAST" THEN PRINT "EAST"
11980 END REPEAT DIRECTION
11990 END DEFINE WHICHWAY

```

To distinguish clearly between your INPUT and the response from the QL we have arranged for the response to be UNDERlined, whilst the backslash before 'DIRECTION' forces a new line.

### A problem case?

When you test this routine you will soon find a common problem — the computer only matches upper case (capital) letters, as strings are compared *exactly*.

Thus, while 'NORTH' equals 'NORTH' and 'north' equals 'north', 'north' cannot equal 'NORTH'.

The simplest thing to do is to just check if the first character of IN\$ is upper case. All capitals have CODEs less than 91 so a large prompt could be displayed, when necessary, reminding you to press CAPSLOCK.

```

11040 IF CODE(IN$)>90 THEN
11050 CSIZE 2,1 : PRINT "press CAPSLOCK!"
      : CSIZE 1,0
11060 NEXT DIRECTION
11070 END IF

```

(In SuperBASIC there is no need to specify the first letter (IN\$(1)) as CODE will return the value for the first character in a string unless a different point is specified.)

A more sophisticated approach is to persuade the computer to automatically convert all letters entered into a particular case. To understand how this operates we need to look at the binary representation of the letters (see Table 2.1). You will notice that the only difference between corresponding upper and lower case letters is that bit 6 (= 32) is always set in lower case but reset in upper case.

Table 2.1: Binary Representation of Upper and Lower Case Letters.

bit	8	7	6	5	4	3	2	1
value	128	64	32	16	8	4	2	1
A	0	1	0	0	0	0	0	1
B	0	1	0	0	0	0	1	0
Y	0	1	0	1	1	0	0	1
Z	0	1	0	1	1	0	1	0
a	0	1	1	0	0	0	0	1
b	0	1	1	0	0	0	1	0
y	0	1	1	1	1	0	0	1
z	0	1	1	1	1	0	1	0

To force both upper and lower case characters into lower case, we therefore need to ensure that bit 6 is always set: to perform the opposite conversion, we need to ensure that bit 32 is not set (that it is reset).

To set bit 6, we need to perform a 'bitwise OR' on the character code. This sets bit 6 whether it was already set OR not.

For example:

```

'A' = 65                                01000001
bitwise OR 32                           00100000
-----
01100001 = 97 ('a')

'a' = 97                                01100001
bitwise OR 32                           00100000
-----
01100001 = 97 ('a')

```

To reset bit 6 we should perform a 'bitwise NOT' on the character code. This resets bit 6 whether or NOT it was set.



For example:

'A' = 65	01000001
bitwise NOT 32	00100000
	<hr/>
	01000001 = 65 ('A')
 'a' = 97	 01100001
bitwise NOT 32	00100000
	<hr/>
	01000001 = 65 ('A')

We will DEFINE a FuNction called GET\$ which will perform either conversion. This uses only the bitwise OR command of the QL for two reasons. The first (very practical) reason is that our QL, at least, doesn't recognise the bitwise NOT command even though it is in the manual! The second reason is that it is then possible to use a single function to convert from lower case to upper case or vice versa simply by passing a parameter.

The GET\$ function is called from line 11030 which replaces the old INPUT line and prompt.

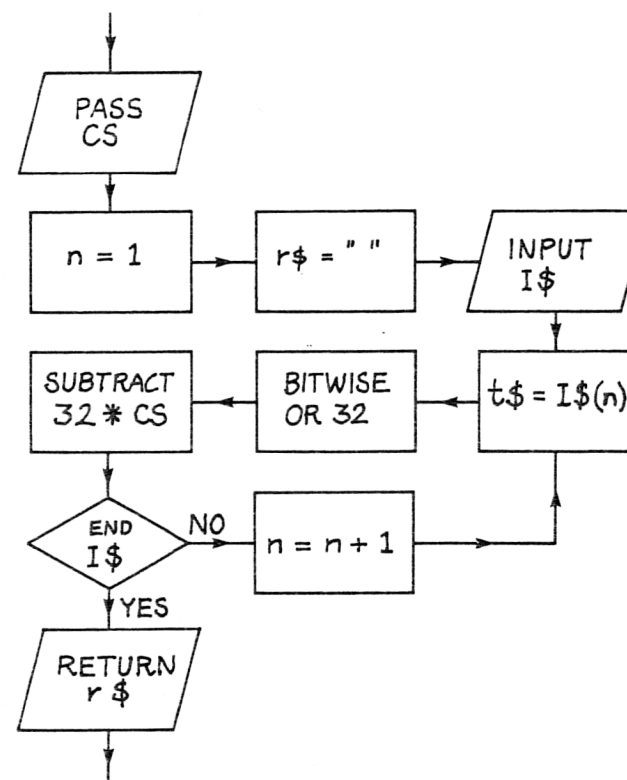
```
11030 IN$=GET$(1) : UNDER 1
11040 REMark DELETED
11050 REMark DELETED
11060 REMark DELETED
11070 REMark DELETED
```

The parameter passed (cs) must be either 0 or 1 where 0 indicates conversion to lower case, and 1 conversion to upper case.

An INPUT (i\$) is made as usual, but then the REPEAT GET\_CHAR loop takes each character in turn (i\$(n)) and this has a bitwise OR (||) with 32 performed on it. This forces bit 6 to be set. However the value of 32\*cs (the parameter passed) is now subtracted from the result. If cs is zero then this will have no effect and lower case will be produced. But if cs is 1 then 32 will be subtracted, which will effectively reset bit 6, whether it was originally set or NOT, and produce upper case. If the end of the INPUT is reached (n=LEN(i\$)) we EXIT GET\_CHAR and the result (r\$) is RETURNed to the calling line as IN\$ (see Flowchart 2.2).

```
20000 DEFine FuNction GET$(cs)
20010 LOCAL i$,n,t$,r$
```

```
20020 n=1
20030 r$=""
20040 INPUT i$
20050 REPEAT GET_CHAR
20060   t$=i$(n)
20070   r$=r$ & CHR$((CODE(t$) || 32)-
      (32*cs))
20080   IF n=LEN(i$) THEN EXIT GET_CHAR
20090   n=n+1
20100 END REPEAT GET_CHAR
20110 RETURN r$
20120 END DEFine GET$
```



Flowchart 2.2: GET\$ PROCEDURE.

(Note that all variables used are LOCAL to the FuNction and are defined in lower case to distinguish them from global variables.)

As it stands, this will modify *all* characters, which produces problems such as a space (CHR\$(32)) being transformed into CHR\$(0) which is non-displayable! We can prevent the conversion of spaces and numerals by restricting the modification to characters having certain CODEs. A simple way to do this is to restrict modification to characters having CODEs greater than 65, by multiplying (32\*cs) by NOT CODE(t\$)<65. Now if the CODE of t\$ is less than 65, then (32\*cs) will NOT be subtracted, and the character will be unchanged.

```
20070      r$=r$ & CHR$((CODE(t$) || 32)-
           (32*cs) * NOT CODE(t$)<65)
```

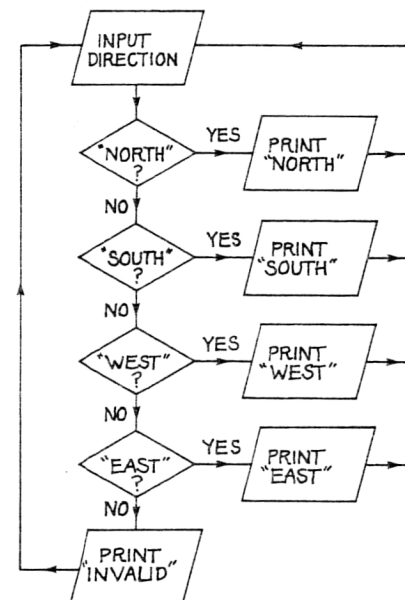
### Invalid requests

If you type in anything other than the four key 'command words' then nothing will be printed, except for another input request. It would be more user-friendly if the computer indicated more clearly than your command was not valid. You could do that by adding a test that none of the command words has been found, but that becomes very long-winded, and effectively impossible when you have a long list of valid words.

```
11140      IF IN$<>"NORTH" AND IN$<>"SOUTH" AND
           IN$<>"WEST" AND IN$<>"EAST" THEN
11150          CSIZE 1,1 : PRINT "INVALID REQUEST"
           : CSIZE 1,0
11160      END IF
```

On the other hand, adding NEXT DIRECTION to the end of each IF-THEN line will force a direct jump back to the INPUT when a valid command is detected. If all the IF tests are not true then the program falls through to line 11150 which prints a warning. Making direct jumps back when a valid word is found is a good idea anyway, as it saves the system making unnecessary tests when the answer has already been found (see Flowchart 2.3).

```
11100      IF IN$="NORTH" THEN PRINT "NORTH" :
           NEXT DIRECTION
11110      IF IN$="SOUTH" THEN PRINT "SOUTH" :
           NEXT DIRECTION
11120      IF IN$="WEST" THEN PRINT "WEST" : NEXT
           DIRECTION
11130      IF IN$="EAST" THEN PRINT "EAST" : NEXT
           DIRECTION
11140      REMark DELETED
11160      REMark DELETED
```



Flowchart 2.3: Deleting Unnecessary Tests.

### Adding some action

That will echo the command given on the screen but of course it does not actually *do* anything. As a model to work with we will introduce Boris the turtle, who will move around the screen in response to our commands. To conveniently display him separately from the text we will divide the screen up into windows in a SCREEN PROCEDURE, which splits the screen vertically with window #1 (white) on the left and #2 (green) on the right. Now text will appear on the right window, and Boris's trail on the left window.

```
12000 DEFine PROCedure SCREEN
12010     MODE 4
12020     WINDOW #1,230,200,257,16
12030     BORDER #1,1,2
12040     CSIZE #1,1,0
12050     PAPER #1,4
12060     INK #1,0
12070     CLS #1
12080     WINDOW #2,230,200,26,16
12090     BORDER #2,1,2
```

```

12100  CSIZE #2,1,0
12110  PAPER #2,7
12120  INK #2,0
12130  CLS #2
12140  INK #0,7
12150  CLS #0
12160  END DEFine SCREEN

```

The START PROCedure must now call SCREEN, set an appropriate drawing SCALE, and move the turtle to his start position. The absolute coordinates of the start position are 10,10 in channel #2, but it is simpler if we express movement as plus and minus in relation to this point by means of variables X% and Y%.

```

10010  SCREEN
10020  SCALE #2,20,0,0
10030  LINE #2,10,10
10040  X%=0 : Y%=0

```

The actual screen movement is dealt with by the TRACK PROCedure, which draws a LINE\_Relative to the last point (0,0). Notice that the updating parameters are passed to TRACK as X1 and Y1.

```

13000  DEFine PROCedure TRACK(X1,Y1)
13010  LINE_R #2,0,0 TO X1,Y1
13020  END DEFine TRACK

```

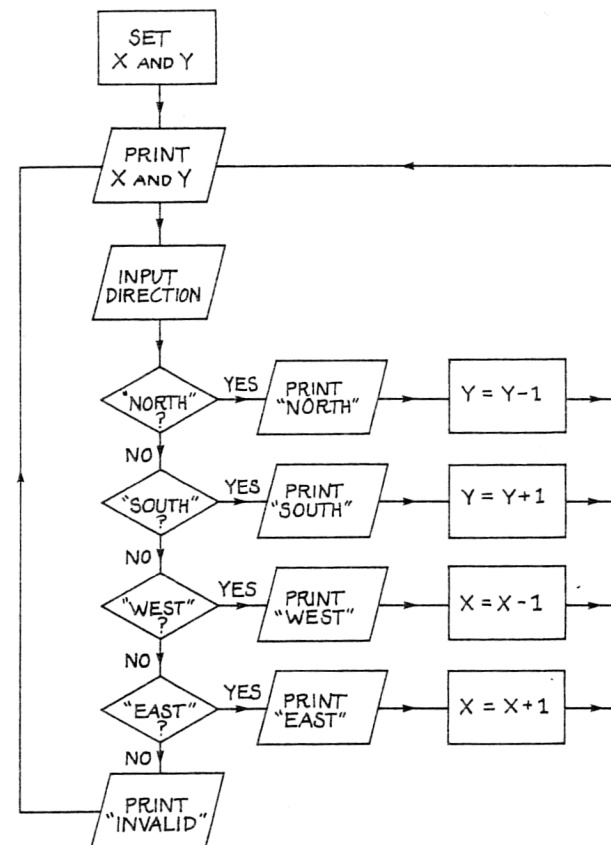
We now need to add the real response to your command, as well as the message indicating that it has been understood, and a printout of your current position (see Flowchart 2.4).

```

11020  UNDER 0 : PRINT "\"DIRECTION?\" \"X=\";
      X%, \"Y=\"; Y%

11100  IF IN$=\"NORTH\" THEN PRINT \"NORTH\" ;
      Y%=Y%+1 : TRACK 0,1 : NEXT DIRECTION
11110  IF IN$=\"SOUTH\" THEN PRINT \"SOUTH\" ;
      Y%=((Y%*3)-3)/3 : TRACK 0,-1 : NEXT
      DIRECTION
11120  IF IN$=\"WEST\" THEN PRINT \"WEST\" ;
      X%=((X%*3)-3)/3 : TRACK -1,0 : NEXT
      DIRECTION
11130  IF IN$=\"EAST\" THEN PRINT \"EAST\" ;
      X%=X%+1 : TRACK 1,0 : NEXT DIRECTION

```



Flowchart 2.4: Adding a Response.

(You may notice that lines 11110 and 11120 look a little strange as  $X\% = ((X\% * 3) - 3) / 3$  and  $Y\% = ((Y\% * 3) - 3) / 3$  effectively only subtract one from X% and Y%. The reason for this long-winded path is that the initial version of the QL had a bug which caused  $-1-1$ ,  $-2-2$ , and  $-4-4$  to all result in 0! As  $-3$  is the smallest number which can be subtracted correctly, X% is multiplied by 3 before subtracting 3 and divided by 3 again! If your machine can successfully calculate  $-1-1=-2$  then you can replace this long version with  $X\% = X\% - 1$  and  $Y\% = Y\% - 1$ , wherever it appears in this book.)

### Using direction PROCedures

Of course that is a very simple example and, particularly where the results



of your actions are more complicated, it may be better to put the responses into individual PROCedures.

```
11100 IF IN$="NORTH" THEN NORTH : NEXT
      DIRECTION
11110 IF IN$="SOUTH" THEN SOUTH : NEXT
      DIRECTION
11120 IF IN$="WEST" THEN WEST : NEXT
      DIRECTION
11130 IF IN$="EAST" THEN EAST : NEXT
      DIRECTION
```

```
14000 DEFine PROCedure NORTH
14010 PRINT "GOING NORTH"
14020 Y%=Y%+1
14030 TRACK 0,1
14090 END DEFine NORTH
```

```
14100 DEFine PROCedure SOUTH
14110 PRINT "GOING SOUTH"
14120 Y%=(Y%*3)-3)/3
14130 TRACK 0,-1
14140 END DEFine SOUTH
```

```
15000 DEFine PROCedure WEST
15010 PRINT "GOING WEST"
15020 X%=(X%*3)-3)/3
15030 TRACK -1,0
15040 END DEFine WEST
```

```
16000 DEFine PROCedure EAST
16010 PRINT "GOING EAST"
16020 X%=X%+1
16030 TRACK 1,0
16040 END DEFine EAST
```

### More versatility

You could extend this use of IF-THEN tests ad infinitum (or rather ad memoriam finitum!) but it is really rather a crude way of doing things which creates problems when you want to make your programs more sophisticated. A more versatile way to deal with command words and responses is to enter them as DATA and then store them in string arrays.

First you must DIMension arrays of suitable length for command words, C\$, and responses, R\$. As only fixed length string arrays are allowed in SuperBASIC, both the length of each element (20), and the number of elements (3) must be defined. (Note that SuperBASIC has a zero element which is also used, thus catering for the four directions.) We now also need to think about how we will match these array elements against the INPUT. The length of an ordinary string input will be the number of characters entered — but the length of the array elements is fixed at 20, with any unused positions being filled with CHR\$(0).

Now an input of:

NORTH

cannot be equal to an array element containing

NORTH (plus 15 empty positions)

unless we force our INPUT string into the same format by declaring it with a DIM (IN\$,20) statement.

```
10050 DIM C$(3,20),R$(3,20),IN$(20)
```

If you put the commands and responses in pairs in the DATA statement then it is more difficult to get them jumbled up and easier to read them in turn into the equivalent element in each array (see Table 2.2).

Table 2.2: Content of Command and Response Arrays.

ELEMENT NUMBER	COMMAND WORD (C\$(n))	RESPONSE (R\$(n))
0	NORTH	GOING NORTH
1	SOUTH	GOING SOUTH
2	WEST	GOING WEST
3	EAST	GOING EAST

At this point we will add some lines to the START PROCedure which will initialise the arrays (fill them with your words). As SuperBASIC does not automatically RESTORE on RUN, this must be done explicitly.

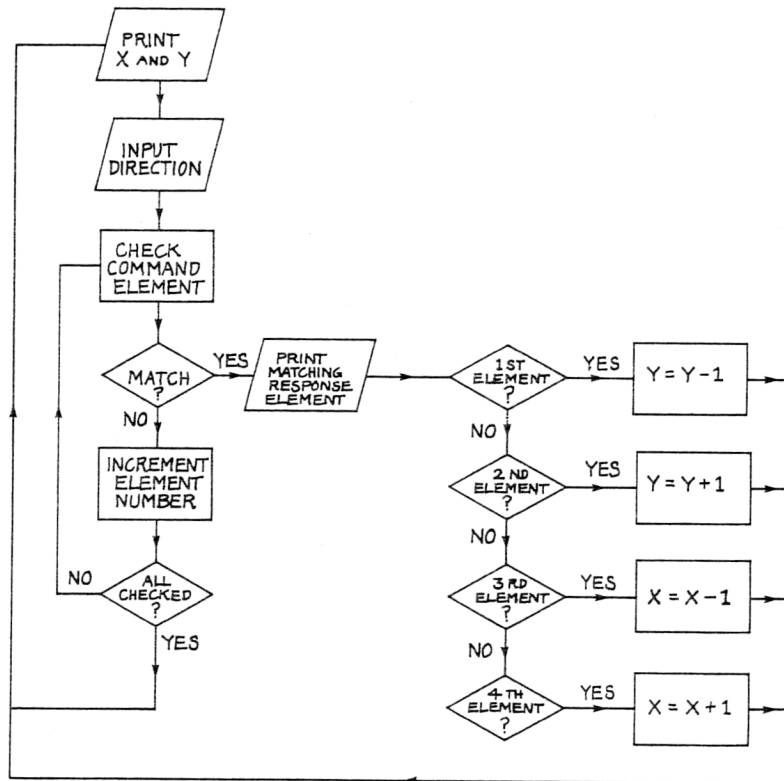
```
10060 RESTORE
10100 DATA "NORTH","GOING NORTH","SOUTH",
          "GOING SOUTH","WEST","GOING WEST",
          "EAST","GOING EAST"
10200 FOR N=0 TO 3
```

```

10210   READ C$(N) : READ R$(N)
10220   END FOR N

```

All those IF-THEN tests can be replaced by a single loop which compares your INPUT with each element of the array containing the command words (C\$) in turn (see Flowchart 2.5).



Flowchart 2.5: More Versatility.

```

11100   FOR N=0 TO 3
11110   IF IN$<>C$(N) THEN
11120   END FOR N
11130   REMark DELETED
11140   REMark DELETED
11160   ELSE
11170   PRINT R$(N)
11200   END IF

```

Now IF your INPUT does not match any of the command words the test falls through, or ELSE the corresponding response element (R\$(N)) is printed out.

Of course we are now back in our original position of actually doing nothing, so we need to add back some actions. We will do this through a new POSITION PROCedure which is called when a match is found.

## 11180 POSITION

We still have a pointer to indicate which word matched the input as N (the number of array elements checked) holds this value. POSITION uses this in the SElect command to move to appropriate routines which are similar to those we wrote earlier, except that there is no need to define the particular message, as this has already been printed as R\$(N).

```

14000 DEFine PROCedure POSITION
14010   SElect ON N
14020   ON N=0
14030   Y%=Y%+1
14040   TRACK 0,1
14100   ON N=1
14110   Y%=((Y%*3)-3)/3
14120   TRACK 0,-1
14140   REMark DELETED
14190   REMark DELETED
14200   ON N=2
14210   X%=((X%*3)-3)/3
14220   TRACK -1,0
14230   REMark DELETED
14290   REMark DELETED
14300   ON N=3
14310   X%=X%+1
14320   TRACK 1,0
14330   END SElect
14390 END DEFine POSITION

```

## Expanding the vocabulary

The arrays can easily be expanded to contain more words and it would be better if we defined the number of words as a variable, WD%, which we would then use to DIMension the arrays and for both the filling and scanning loops. This produces a general routine which is easily modified.

```
10050 WD%=3 : DIM C$(WD%,20),R$(WD%,20),
      IN$(20)
```

```
10200 FOR N=0 TO WD%
```

```
11100   FOR N=0 TO WD%
```

For example we can add intermediate compass directions which change both X and Y axes.

```
10050 WD%=7 : DIM C$(WD%,20),R$(WD%,20),
      IN$(20)
10110 DATA "NORTH EAST","GOING NORTH EAST"
      ,"SOUTH EAST","GOING SOUTH EAST"
10120 DATA "SOUTH WEST","GOING SOUTH WEST"
      ,"NORTH WEST","GOING NORTH WEST"
```

and add some more actions:

```
14330 REMark DELETED
14390 REMark DELETED
14400   ON N=4
14410     Y%=Y%+1 : X%=X%+1
14420     TRACK 1,1
14500   ON N=5
14510     Y%=(Y%*3-3)/3 : X%=X%+1
14520     TRACK 1,-1
14600   ON N=6
14610     Y%=(Y%*3-3)/3 : X%=(X%*3-3)/3
14620     TRACK -1,-1
14700   ON N=7
14710     Y%=Y%+1 : X%=(X%*3-3)/3
14720     TRACK -1,1
14730   END SElect
14740 END DEFine POSITION
```

### Removing redundancy

All the responses so far have included the word 'GOING' and this word has actually been typed into each DATA statement. Now typing practice is very good for the soul but it would be much more sensible to define this common word as a string variable. Notice that a space is included at the end to space it from the following word. All occurrences of the word 'GOING' can be deleted from the DATA and G\$ combined with each key word in the response instead.

```
10100 DATA "NORTH","NORTH","SOUTH","SOUTH",
      "WEST","WEST","EAST","EAST"
```

```
10110 DATA "NORTH EAST","NORTH EAST","SOUTH
      EAST","SOUTH EAST"
```

```
10120 DATA "SOUTH WEST","SOUTH WEST","NORTH
      WEST","NORTH WEST"
```

```
10130   G$="GOING "
```

```
11170   PRINT G$,R$(N)
```

Now that is starting to look rather silly as both arrays contain exactly the same words, so why not get rid of the response arrays, R\$, and simply print C\$(N)? Well, in this case you could do that without any problem, but of course where the responses are not simply a repetition of the input (as is very often the case) the second array is essential.

If you look hard at all those action PROCedures you will realise that they all do essentially one thing — update the values of X% and Y%. Now we could include that information in the original DATA and get rid of them altogether! We need to add two more arrays to hold the X and Y coordinates, add the appropriate values into the DATA lines after each response, and READ in the information in blocks of four (INPUT, RESPONSE, X-MOVE, Y-MOVE — see Table 2.3).

Table 2.3: X and Y Moves Incorporated into Arrays.

ELEMENT NUMBER	COMMAND WORD C\$(n)	RESPONSE R\$(n)	X-MOVE X(n)	Y-MOVE Y(n)
1	NORTH	NORTH	0	-1
2	SOUTH	SOUTH	0	1
3	WEST	WEST	-1	0
4	EAST	EAST	1	0
5	NORTH-EAST	NORTH-EAST	1	-1
6	SOUTH-EAST	SOUTH-EAST	1	1
7	SOUTH-WEST	SOUTH-WEST	-1	1
8	NORTH-WEST	NORTH-WEST	-1	-1

```
10050 WD%=7 : DIM C$(WD%,20),R$(WD%,20),IN$
      (20),X(WD%),Y(WD%)
```

```
10100 DATA "NORTH","NORTH",0,1,"SOUTH",
      "SOUTH",0,-1,"WEST","WEST",-1,0,
      "EAST","EAST",1,0
```

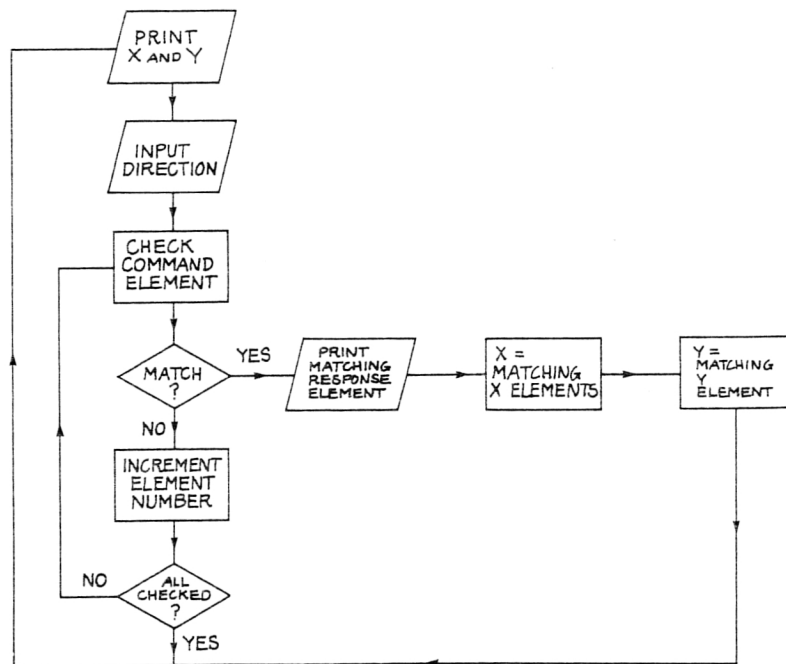
```

10110 DATA "NORTH EAST","NORTH EAST",1,1,
        "SOUTH EAST","SOUTH EAST",1,-1
10120 DATA "SOUTH WEST","SOUTH WEST",-1,-1
        ,"NORTH WEST","NORTH WEST",-1,1

10210 READ C$(N) : READ R$(N) : READ X(N)
      : READ Y(N)

```

Now we can delete all the redundant lines and modify the TRACK PROCedure so that X% and Y% are suitably updated (see Flowchart 2.6).



Flowchart 2.6: Using Linked Arrays.

```

14010 X%=(X%#3)+(X(N)#3)/3 :
      Y%=(Y%#3)+(Y(N)#3)/3
14020 TRACK X(N),Y(N)
14030 REMark DLINE 14030 TO 14730

```

This overall pattern of putting all the information into a series of linked

arrays is a very common feature which is used in several of the later programs in this book.

### Abbreviated commands

So far we have always used complete words as commands, but that means that you have to do a lot of typing to give the machine your instructions. If you are feeling lazy, you might think of changing the command words to the first letter of the word only, and then INPUT a single letter. However, unless you start using random letters, that will only start work as long as no two words start with the same letter! To code all the eight compass directions used above, we will have to use up two letters: N, NE, E, SE, S, SW, W, NW.

```

10100 DATA "N","NORTH",0,1,"S","SOUTH",0,-
        1,"W","WEST",-1,0,"E","EAST",1,0
10110 DATA "NE","NORTH EAST",1,1,"SE",
        "SOUTH EAST",1,-1
10120 DATA "SW","SOUTH WEST",-1,-1,"NW",
        "NORTH WEST",-1,1

```

Notice that it is only the actual command words which have changed and that the computer gives a full description of the direction, as we are still using that second array which holds the response.

### Partial matching

In all the programs above we have always checked that the input matched a word in the command array *exactly*. However it would be useful if we could allow a number of similar words to be acceptable as meaning the same thing. For example, you could check whether the first letter of the input word matched the abbreviated keyword by only comparing the first character (taking IN\$(1)).

```
11080 IN$=IN$(1)
```

That will work with NORTH, SOUTH, EAST and WEST, but there are obvious problems in dealing with the intermediate positions, so we will get rid of these positions again.

```

10050 WD%=3 : DIM C$(WD%,20),R$(WD%,20),
        IN$(20),X(WD%),Y(WD%)
10110 REMark DELETED
10120 REMark DELETED

```

In addition there are lots of words beginning with the letters N, S, E and W — all of which would be equally acceptable to the machine as a valid direction.

For example:

NOT NORTH

would produce:

GOING NORTH

A more selective process is to match a number of letters instead of just one. In this example, the first three letters of the four main directions are quite characteristic.

NOR  
SOU  
EAS  
WES

If you use these as command words then, for example:

NOR  
NORTH  
NORTHERN  
and NORTHERLY

will all be equally acceptable, but:

NOT  
NEARLY  
NOWHERE  
and NONSENSE

will all be rejected.

All we need to do is to take the first three letters of the input, IN\$(1 TO 3), and compare them with a revised DATA list.

```
10100 DATA "NOR","NORTH",0,1,"SOU","SOUTH",
        ,0,-1,"WES","WEST",-1,0,"EAS","EAST",
        ,1,0
```

```
11080 IN$=IN$(1 TO 3)
```

## Sequential commands

In the routines above we have dealt with the intermediate compass positions as separate entities, but if we could give a sequence of commands at the same time we would not need to do this. There is always more than one way to get to any point and if more than one command word could be understood at the same time we would not have to worry about checking for directions such as 'NORTH EAST' as they could be dealt with by the combination of 'NORTH' and 'EAST'.

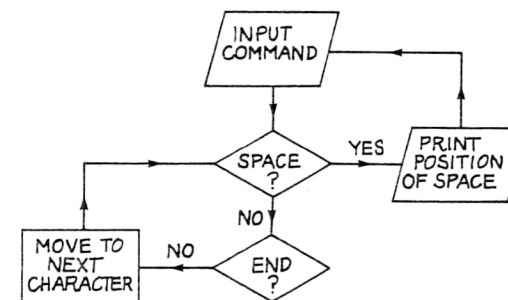
This brings us to the very significant question of how to split an input into words. First you must ask yourself how you recognise that a series of characters make up a separate word? The answer, of course, is that you see a *space* between them. Now, if we look for spaces we can break the input into separate words which we can look at individually. The easiest way to look for spaces is with the INSTR command which searches the whole of a designated search string for a match with a second target string.

To begin with we will incorporate INSTR into a WORDSPLIT FuNction which is now called from line 11080.

```
11080 WORDSPLIT
```

```
15000 DEFine FuNction WORDSPLIT
15010 SP%=" " INSTR IN$
15030 PRINT "SP% ";SP%
15090 END DEFine WORDSPLIT
```

This starts by checking whether the first character in IN\$ is a space. If it is not a space, then it will automatically continue checking until the end of IN\$ is reached. If no space is found in the whole of IN\$ then SP% will be set to zero. If a space is found the value of SP% will be the number of characters along IN\$ that the space is located (see **Flowchart 2.7**). The temporary line 15030 prints out SP% so that you can observe INSTR in action.



Flowchart 2.7: Locating the Position of a Space.

Try this out with:

NOR WES

SP% 4

NORTH WEST

SP% 6

NOR NOR WEST

SP% 4

(Note that you will also get an 'Invalid request' message for the moment as IN\$ is no longer converted to the first three characters only.)

Although the length of the word is accounted for by SP%, only the first space is found. To find all the spaces we are going to have to work harder.

First of all a space needs to be added to the front end of IN\$, so that the first word has the same format as the others, and we must define the start position of the search (ST%) as zero.

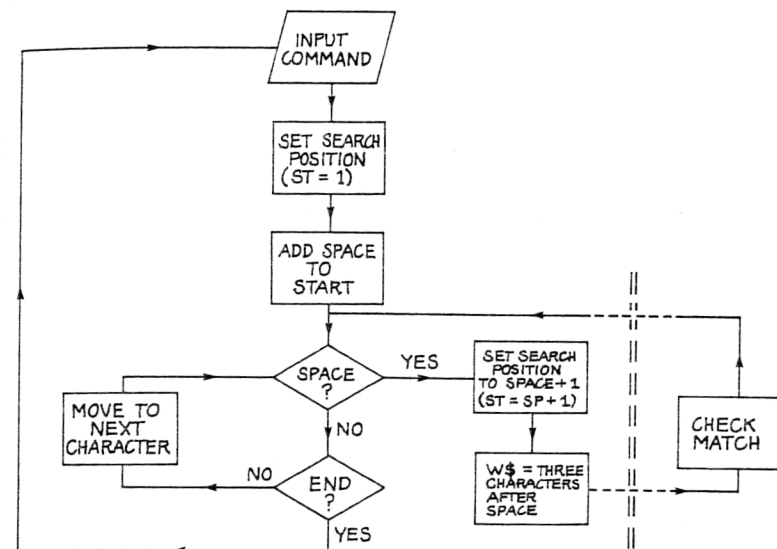
```
11080   IN$=" " & IN$ : ST%=0
11090   WORDSPLIT
```

The WORDSPLIT FuNction is now modified to find and cut out each word in the INPUT (see **Flowchart 2.8**). Once a space has been found (at SP%) a new search start position is defined as one character further along IN\$ (at ST%), a word (W\$) cut out as the first three characters following the space (ST% TO ST%+2), and the INPUT string (IN\$) truncated so that it only contains the unchecked part of the entry (IN\$(ST% TO)).

```
15010   SP%=" " INSTR IN$
15030   ST%=SP%+1
15070   W$=IN$(ST% TO ST%+2) : IN$=IN$(ST% TO)
```

As WORDSPLIT was DEFINed as a FuNction, we can use it to return different values. We will RETURN minus one if no space is found (SP%=0), and zero if a space is found and a word cut out.

```
15020   IF SP%=0 THEN RETURN -1
15080   RETURN 0
```



Flowchart 2.8: Searching for a Keyword.

Now we can use the value RETURNed by WORDSPLIT to EXIT the REPEAT WORDS loop as soon as no word is found.

```
11090   IF WORDSPLIT THEN EXIT WORDS
```

Now typing:

NORTH WEST

produces:

GOING NORTH  
GOING WEST

and even:

NOR NOR EAST

is decoded as:

GOING NORTH

GOING NORTH

GOING EAST



It would be a lot neater if we deleted all those redundant 'GOINGs' and put all the reported directions on the same line. We need to PRINT G\$ once, immediately before the INSTR check. Now each time we go through the loop comparing the current word with those stored, we 'PRINT R\$(N);' if there is a match. As there is a semicolon after this the words will be printed on the same line but we also need to add spaces between them.

```
11080      IN$=" " & IN$ : ST%=0 : PRINT G$;
```

```
11170      PRINT R$(N);" ";
```

Now:

NORTH EASTERLY SOUTH WEST

sends you neatly round in circles

GOING NORTH EAST SOUTH WEST

## CHAPTER 3

### Understanding Natural Language

So far we have only communicated with the computer in a very restricted way as it has only been programmed to understand a very few words or letters and it only recognises those if they are entered in exactly the right way. For example, if you put a space before or after your command as you INPUT it then it will be rejected. This is because we are comparing whether the two strings match exactly.

However, in the real world everyone uses what is known as natural language, which is a very sophisticated and extremely variable thing which only the human brain can cope with effectively. Even if we forget for the moment the differences between 'English' and 'American' or even regional dialects of either of those (can 'Ow bist old but' really mean 'How are you old friend?'), dealing with language has an infinite number of problems.

Even the most sophisticated systems in the world cannot cope with everything. There is an old story which illustrates this point very well. The CIA developed a superb translation program which could instantly convert English into Russian and vice versa. In the hope of impressing the President they laid on a demonstration of its capabilities in which it converted everything he said into Russian, spoke that, and then retranslated the Russian back into English. He was most impressed and was totally absorbed until one of his aides reminded him that he had forgotten that the First Lady was waiting for him outside. When he ruefully commented 'out of sight, out of mind' he was amazed to hear the machine come back with 'invisible maniac'!

#### Dealing with sentences

Everyone knows that real language is made up of sentences, but what exactly do we mean by a sentence? Well, the most obvious way we recognise a sentence is that we see a full stop! However, if we are going to be able to deal with sentences we are going to have to think a lot harder than that.

The Oxford Dictionary definition includes 'a series of words in connected speech or writing, forming grammatically complete expression of single thought, and usually containing subject and predicate, and conveying statement, question, command or request' but also concedes

that it is used loosely to mean 'part of writing or speech between two full stops'. Phew! Can somebody translate that into everyday English, please? The intricacies and illogicalities of the English language are infamous, so how can we expect a computer to cope?

### Parsing the parcel

Before we can understand a sentence we must break it down into its component parts before we can analyse the significance of each individual segment. This process of dividing up the sentence is known as 'parsing' by the cognoscenti, so there's one more piece of jargon to impress your friends if you are that way inclined.

Let's start by looking at some simple examples of sentences.

I WANT.

consists of a subject I and a verb WANT.

I WANT BISCUITS.

also has an object BISCUITS.

I WANT CHOCOLATE BISCUITS.

qualifies the object with an adjective CHOCOLATE.

I SOMETIMES WANT CHOCOLATE BISCUITS.

qualifies the verb with an adverb SOMETIMES.

The most important word in all the above examples was 'WANT', as it conveyed the main idea. The second example was more informative as it indicated that only one particular type of object, BISCUITS, was wanted. The addition of an adjective, CHOCOLATE, gave further information on the type of object wanted, but life became more uncertain again when the adverb SOMETIMES was included.

Now how could a computer program decode such sentences? The answer must be to find some logical structure in the sentence, so what 'rules' could we lay down for this example?

- 1) All started with a subject, I, and ended with a full stop.
- 2) The last word was always the object BISCUITS (unless there was no object and only two words).

- 3) If the word before the object was not the verb WANT, it was an adjective, CHOCOLATE.
- 4) If the word before the verb was not the subject, I, it was an adverb, SOMETIMES.

Let's write a program in which we give the computer sentences and ask it to break them up into their component parts.

To begin with, we will set up a suitable SCREEN format with three windows. Channel #0 at the bottom receives your input, and the rest of the screen is split horizontally into windows #1 and #2. Window #1 (lower) shows the final results of the program, whilst window #2 (upper) displays the workings of certain subroutines.

### 30 SCREEN

```

10000 DEFine PROCedure SCREEN
10010  MODE 4
10020  CLS
10030  WINDOW #0,435,40,36,216
10040  WINDOW #1,455,100,26,116
10050  WINDOW #2,455,100,26,16
10060  BORDER #0,5,4
10070  BORDER #1,3,2
10080  BORDER #2,3,2
10090  PAPER #0,0
10100  PAPER #1,7
10110  PAPER #2,4
10120  INK #0,7
10130  INK #1,0
10140  INK #2,0
10150  CSIZE #0,1,0
10160  CSIZE #1,1,0
10170  CSIZE #2,1,0
10180  CLS #0 : CLS #1 : CLS #2
10190 END DEFine SCREEN

```

We need to give it a vocabulary of objects, adjectives and adverbs to work with, by calling a SET\_UP PROCedure which READs these from DATA and stores them in arrays OB\$(n,10), AJ\$(n,10) and AV\$(n,10), according to type. Note that the length of the longest word (10) must be taken into account when DIMensioning the arrays and that the number of each type of word is defined as a variable (OB%, AJ%, AV%) so that it is easy to add more words later.

```

10 RESTORE
40 SET_UP

11000 DEFine PROCedure SET_UP
11010  OB%=5 : AJ%=5 : AV%=2 : DIM OB$(OB%,10)
      ,AJ$(AJ%,10),AV$(AV%,10)
11020  DATA "BISCUITS","BUNS","CAKE","COFFEE"
      ,"TEA","WATER"
11030  DATA "CHOCOLATE","GINGER","JAM","COLD"
      ,"HOT","LUKEWARM"
11040  DATA "ALWAYS","OFTEN","SOMETIMES"
11050  FOR N=0 TO OB%
11060  READ OB$(N)
11070  END FOR N
11080  FOR N=0 TO AJ%
11090  READ AJ$(N)
11100  END FOR N
11110  FOR N=0 TO AV%
11120  READ AV$(N)
11130  END FOR N
11140 END DEFine SET_UP

```

Now we need to INPUT the sentence to be parsed, using the GET\$(1) FuNction described previously, and a REPEAT IN loop. (Don't forget that you can use MERGE to transfer the original GET\$ lines from the program described in the last chapter!)

The sentence must be broken into words (see Flowchart 3.1). To make life easier, we will add a space on to the end of IN\$, so that the format of the last word looks just like that of other words, and also a dummy character (\*) right at the end for reasons which are explained below.

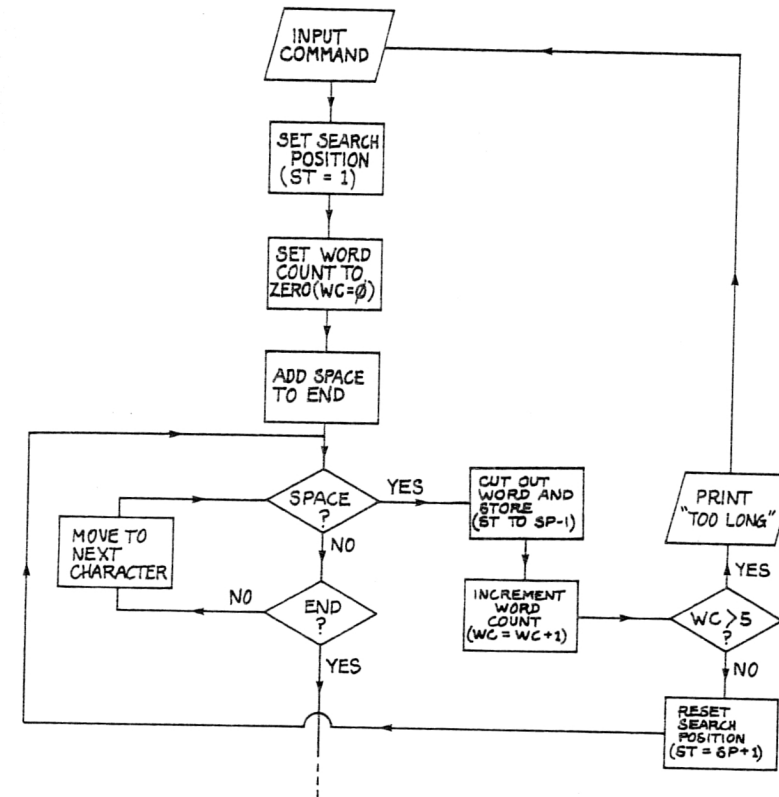
```
120  IN$=IN$ & " *"
```

Once again we will use an INSTR search for spaces, and then cut out and store each word. This is done here with the REPEAT WORDS loop and the WORDSTORE FuNction. The initial search start is defined as ST% = 1.

```

130  ST%=1
170  REPEAT WORDS
180  IF WORDSTORE THEN EXIT WORDS
190  END REPEAT WORDS

```



Flowchart 3.1: Cutting Out Words.

If a space is not found ( $SP\% = 0$ ) then the end of the sentence has been reached, and WORDSTORE RETURNS a value of -1. If WORDSTORE RETURNS any value other than zero then we EXIT the WORDS loop.

```
12000 DEFine FuNction WORDSTORE
```

```

12020  SP%=" " INSTR IN$
12030  IF SP%=0 THEN RETURN -1

```

```
12090 END DEFine WORDSTORE
```

If a space is found, the section of IN\$ from ST% (current search start) to  $SP\% - 1$  (current space - 1 = length of word) is cut out, the word count (WC%) incremented, and the section stored in a word store array,  $W$(WC\%)$ .

```

20 DIM W$(5,10)

60 WC%=-1

12040 WC%=WC%+1

12060 W$(WC%)=IN$(ST% TO SP%-1)

```

To begin with, ST% = 1 so that the search starts at the first character in the input string, and the word count variable, WC%, is set to zero (ie -1 +1) so that the first word found is stored in the zero element of the word store array. The word count is incremented in each cycle so that the next element of the array W\$ is used next time.

The length of IN\$ is now reduced by cutting off the word already stored from the front end to leave IN\$(SP%+1 TO) and a value of 0 RETURNed by the FuNction. As WORDSTORE is therefore zero, the WORDS loop is repeated. The dummy asterisk at the end is needed as the new IN\$ is always defined as one more than the last space, so that the ultimate end of IN\$ must *not* be a space.

```

12070 IN$=IN$(SP%+1 TO)
12080 RETURN 0

```

Adding the following lines will produce a printout in the upper window showing the reducing length of IN\$ as the search proceeds.

```

150 UNDER #2, 1 : PRINT #2,"IN$"\ :
    UNDER #2, 0

12010 PRINT#2,, IN$

```

A check is made that there are not more than six (0 to 5) words in the sentence, as that would exceed the array size. If this is true then WC% is reset to -1, and WORDSTORE RETURNS -1, so that we EXIT the WORDS loop.

```

12050 IF WC%>5 THEN PRINT "SENTENCE TOO
    LONG" : WC%=-1 : RETURN -1

```

When the search is completed (END REPEAT WORDS), the list of words found is printed out in the lower window.

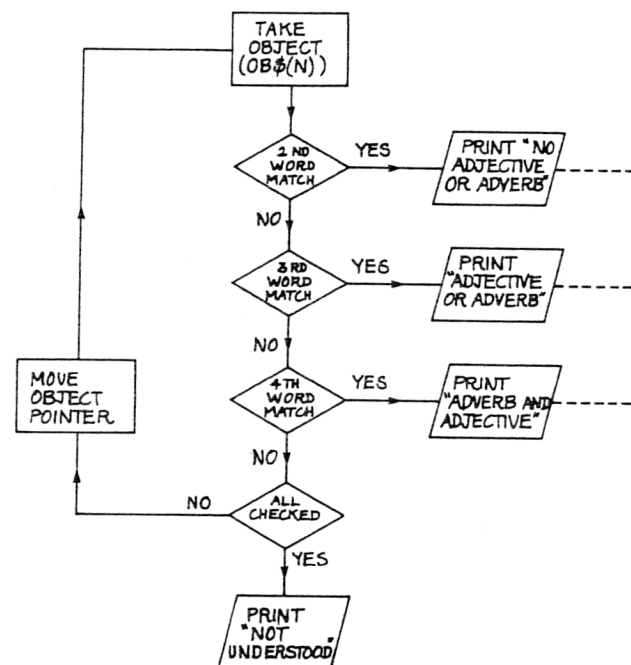
```

160 UNDER #1, 1 : PRINT #1,"W$(N)\" :
    UNDER #1, 0

200 FOR N=0 TO WC%
210 PRINT, W$(N);" "
220 END FOR N

```

A test is now made to see whether there is a match between words in the sentence W\$(N) and the objects in the vocabulary array OB\$(N) (see **Flowchart 3.2**). Only words 2, 3 and 4 are checked as these are the only possible positions for the object in our restricted sentence format. Three different PROCedures are jumped to according to the position of the matching word in the sentence. If no match is found a message is printed and a new input requested.



Flowchart 3.2: Looking for a Match.

```

230 FOR N=0 TO OB%
240 IF W$(2)=OB$(N) THEN NEITHER :
    NEXT IN

```

```

250      IF W$(3)=OB$(N) THEN EITHER :
        NEXT IN
260      IF W$(4)=OB$(N) THEN BOTH :
        NEXT IN
270      END FOR N
280      PRINT \,"object not found"
290      END REPEAT IN

```

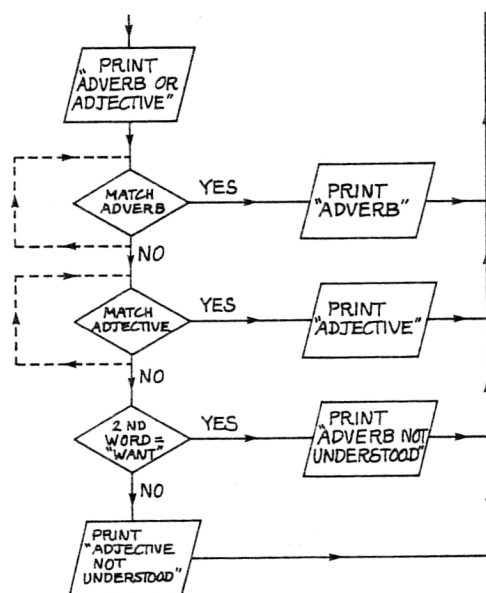
If the object was found as word 3, then there was *neither* adjective nor adverb.

```

1000 DEFine PROCedure NEITHER
1010  PRINT \,"no adjective or adverb"
1020 END DEFine NEITHER

```

If the object was found as word 4, there could have been *either* an adjective or an adverb in the sentence (see Flowchart 3.3).



Flowchart 3.3: Adverb or Adjective.

```

2000 DEFine PROCedure EITHER
2010  PRINT \,"either adjective or adverb"

```

First we check for a match between the second word and the contents of the adverb array.

```

2020      FOR N=0 TO AV%
2030      IF W$(1)=AV$(N) THEN PRINT ,
        "ADVERB" : RETURN
2040      END FOR N

```

If no match is found then we check the third word against the adjective list.

```

2050      FOR N=0 TO AJ%
2060      IF W$(2)=AJ$(N) THEN PRINT ,
        "ADJECTIVE" : RETURN
2070      END FOR N

```

If a match is not found in either of these lists, then it would be useful to indicate which word was not understood. The simplest answer is to check whether the second word was not the verb 'WANT', as in that case the second word must have been an adverb. On the other hand if the second word was the verb then the third word must have been an adjective. Notice that the actual word which did not match is now included in the message.

```

2080      IF W$(1) <> "WANT" THEN PRINT \
        "ADVERB ";W$(1); " NOT UNDERSTOOD" :
        RETURN
2090      PRINT \ "ADJECTIVE ";W$(2); " NOT
        UNDERSTOOD" : RETURN
2100 END DEFine EITHER

```

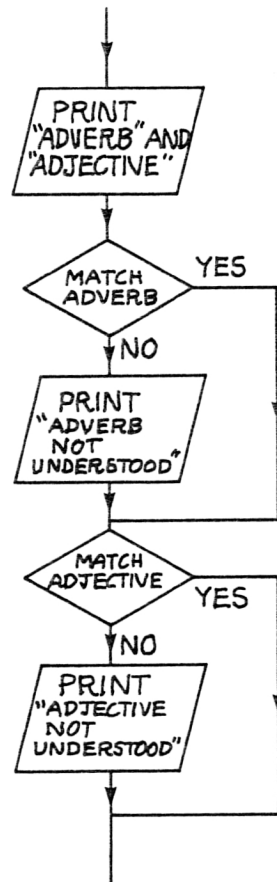
If a match is found in any test then we RETURN. Note that these possibilities are exclusive and that in four words we can only have one or the other.

Where *both* adverb and adjective are present we must check for both (with ADV\_CHECK and ADJ\_CHECK), and therefore a match in the first test also jumps on to the second test (see Flowchart 3.4).

```

3000 DEFine PROCedure BOTH
3010  PRINT \ "ADVERB and ADJECTIVE"
3020  ADV_CHECK
3030  ADJ_CHECK
3040 END DEFine BOTH

```



Flowchart 3.4: Adverb and Adjective.

If an ADVerb is found then we RETURN to the *last* PROCedure (ie BOTH) and continue with ADJ\_CHECK. Otherwise the word not recognised is reported before ADJ\_CHECK is called.

```

4000 DEFine PROCedure ADV_CHECK
4010  FOR N=0 TO AV%
4020    IF W$(1)=AV$(N) THEN RETURN
4030  END FOR N
4040  PRINT "adverb ";W$(1); " not understood"
4050 END DEFine ADV_CHECK

```

ADJ\_CHECK works in the same way.

```

5000 DEFine PROCedure ADJ_CHECK
5010  FOR N=0 TO AJ%
5020    IF W$(3)=AJ$(N) THEN RETURN
5030  NEXT N
5040  PRINT "adjective ";W$(3); " not understood"
5050 END DEFine ADJ_CHECK

```

### What about punctuation?

As we already said, you usually recognise the end of a sentence because it has a full stop, although when you type into a computer you usually forget all about such trivialities. But what will happen in the program so far if some 'clever' user puts in the correct punctuation? If you think for a moment you will realise that the computer will start complaining as it will no longer recognise the last word, as this will actually be split out as the word *plus* the full stop.

We therefore need to check if the last character in the input string IN\$ is a full stop. The best place to check PUNCTUATION seems to be immediately after the INPUT. If the end character (EN\$ = IN\$(LEN(IN\$))) is a full stop then simply CHOP this character off and then RETURN.

### 90 PUNCTUATION

```

6000 DEFine PROCedure PUNCTUATION
6010  EN$=IN$(LEN(IN$))
6020  IF EN$="." THEN CHOP : RETURN
6050 END DEFine PUNCTUATION

```

```

7000 DEFine PROCedure CHOP
7010  IN$=IN$(1 TO LEN(IN$)-1)
7020 END DEFine CHOP

```

Other punctuation marks may also appear at the end of the sentence so perhaps we should look closer at the last character. More useful sentence terminators are the question and exclamation marks which often indicate the context of the words.

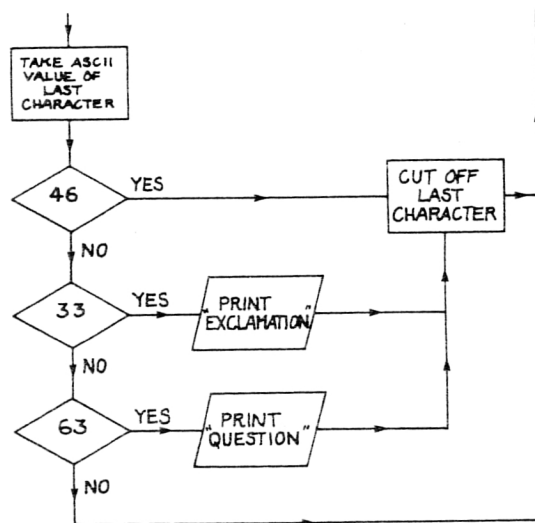
```

6030  IF EN$="?" THEN CHOP : PRINT #0,"
      QUESTION?"\
6040  IF EN$="!" THEN CHOP : PRINT #0,"
      EXCLAMATION"\

```



In many dialects of BASIC, the INPUT command will not accept anything after a comma, which it reads as data terminator, but fortunately SuperBASIC has no objections. Commas may be useful in indicating different parts of a sentence, which could be examined as 'sub-sentences' in their own right. However, in simple cases they are best deleted and replaced by spaces before the sentence is broken into words (see Flowchart 3.5). Note that this will only function totally correctly if there is no space after the comma, as any space following a replaced comma will be seen as a new word. If no comma is found (CM% = 0) then we RETURN, otherwise the lefthand part of IN\$ (up to the comma), and the righthand part of IN\$ (beyond the comma) are taken and joined together with a space.



Flowchart 3.5: Dealing with Punctuation.

## 100 COMMA

```

8000 Define PROCedure COMMA
8010 REPeat comloop
8020 CM%="," INSTR IN$
8030 IF CM%=0 THEN RETURN
8040 IN$=IN$(1 TO CM%-1) & " " & IN$(CM%+1
      TO )
8050 END REPeat comloop
8060 END Define COMMA

```

Apostrophes can be dealt with in the same way, except that we do not replace them with a space but simply close up the words.

## 110 APOSTROPHE

```

9000 DEfine PROCedure APOSTROPHE
9010 REPeat aposloop
9020 AP%="'" INSTR IN$
9030 IF AP%=0 THEN RETURN
9040 IN$=IN$(1 TO AP%-1) & IN$(AP%+1 TO )
9050 END REPeat aposloop
9060 END DEfine APOSTROPHE

```

## A sliding search approach

Although the method of examining a sentence described above will work it has the disadvantage that it requires the sentence to be entered in a particular restricted format. For example if you enter:

I WANT REALLY HOT CHOCOLATE CAKE

the computer will report:

OBJECT NOT FOUND

as it only looks for objects as far as the fifth word.

Using a sliding search of the whole sentence for each keyword, without first dividing the sentence down into words, has the advantage that it allows a completely free input format. In this approach we take the first keyword and try to match it against the same number of letters in IN\$, starting at the first character. If this test fails then it is automatically repeated, starting from the second character, etc, until a match is found or the end of IN\$ is reached. For example if IN\$ was 'I WANT CAKE' and the first keyword was 'CAKE', the comparisons would be:

pass 1	I	WA	
pass 2		WAN	
pass 3		WANT	
pass 4		ANT	
pass 5		NT	C
pass 6		T	CA
pass 7			CAK
pass 8			CAKE (match found)

We can use much of our existing program, but substantial changes are also required. Therefore delete all the lines from 80 up to 9999 with 'DLINE 80 TO 9999' as a direct command and modify the DIM statement in line 20 to expand the size of the wordstore array (W\$(N)) to twenty words. The WORDSTORE FuNction will not be used here so you can also remove that with 'DLINE 12000 TO 12090'.

```

10 RESTORE
20 DIM W$(19,10)
30 SCREEN
40 SET_UP
50 REPEAT IN
60   WC%=-1
70   AT #0, 1,1 : IN$=GET$(1)
90   CLS #1 : CLS #2

```

To replace the WORDSTORE FuNction we have a somewhat similar FIND(T\$) PROCEDURE (see Flowchart 3.6). This searches IN\$ for the temporary string (T\$) which is passed to it as a parameter. As T\$ is passed when FIND is called, it can be used to perform an INSTR check for any particular string. If no match is found we RETURN. To report what has been found, and so that we can use the words discovered later, we will store each matched word (T\$) in an array as it is detected. We have already expanded the word store array, W\$, to hold up to 20 words (which should be enough for even a very verbose sentence!).

```

1000 DEFine PROCEDURE FIND(T$)
1010   IN%=T$ INSTR IN$
1020   IF IN%=0 THEN RETURN
1040   WC%=WC%+1
1050   W$(WC%)=T$
1080   PRINT #2,,,T$
1090 END DEFine FIND

```

Each object can be compared with IN\$ by forming a loop, and similar checks can be made for matching with words in the adverb and adjective arrays.

```

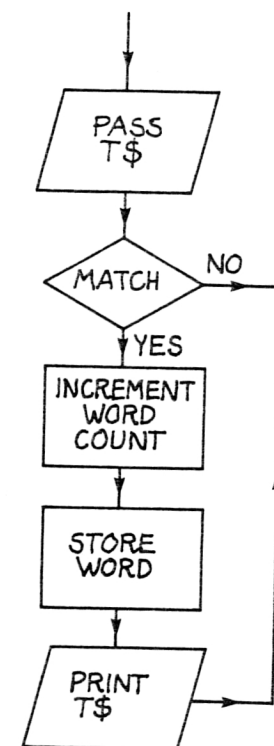
120   FOR M=0 TO OB%
130     FIND(OB$(M))
140   END FOR M
150   FOR M=0 TO AV%
160     FIND(AV$(M))
170   END FOR M

```

```

180   FOR M=0 TO AJ%
190     FIND(AJ$(M))
200   END FOR M

```



Flowchart 3.6: Find (T\$).

The program waits until the time delay (500) runs out, or a key is pressed, before clearing out the INPUT window and REpeating the request for a sentence.

```

250   DUMMY%=INKEY$(500)
260   CLS #0
270   END REPEAT IN

```

### Partial matching

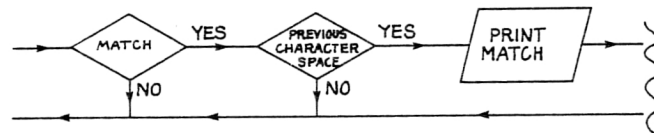
One advantage of the sliding search is that you can easily arrange to recognise a series of connected words by only looking for some key

characters. This is obviously useful as it saves you having to put both single and plural nouns such as BISCUIT and BISCUITS. If you amend the DATA in line 11020 as below then both will now be recognised.

```
11020 DATA "BISCUIT","BUN","CAKE","COFFEE"
      , "TEA", "WATER"
```

However life is not that simple, as using BUN rather than BUNS can produce some unexpected results. On the plus side it will detect BUN, BUNS, and BUNFIGHT but unfortunately BUNCH, BUNDLE, BUNGALOW, BUNGLE, BUNK, BUNION, and BUNNY as well!

This problem is not restricted to prefixes as the computer will also not distinguish between HOT and SHOT. You could include a check that the character before the start of each match was a space (ie that this was the start of a word, see **Flowchart 3.7**). IN% gives the current start of word position, so IN\$(IN%-1) is the character before this, and we RETURN if this is a space.



Flowchart 3.7: Checking That This is the Start of a Word.

```
1030 IF IN$(IN%-1) <> " " THEN RETURN
```

For this to function correctly on the first word, we must add a space to the start of IN\$.

```
80 IN$=" " & IN$
```

In a similar way you could use checks on the next letter after the match, or the length of the word, to restrict recognised words.

### Putting things in order

Although we have now detected all the words in the sentence, regardless of their position or what else is present, they are found and stored in the order in which they appear in the DATA. This is because the comparison starts with the first item in the object array rather than the first word in the sentence. It would be useful if we could rearrange the wordstore array so that the words in it were in the order in which they appeared in the sentence.

To do that we must keep a record of the sentence position of the word, IN%, and word count, WC%, as each word is matched in a new word position array, WP%. This is a two-dimensional array with the sentence position kept in the first element, WP(WC%,0), and the word count, WP(WC%,1), in the second. To make the display clearer, 'word' and 'position' (ie character position of start of the match in IN\$) labels have been added.

```
20 DIM W$(19,10) : DIM WP(19,1)

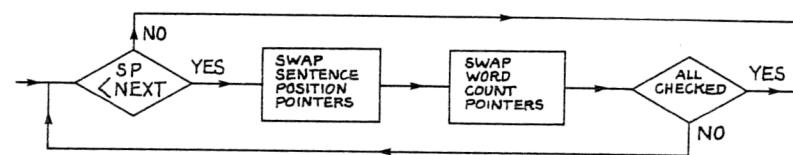
110 PRINT "word", "position"

1060 WP(WC%,0)=IN% : WP(WC%,1)=WC%
1070 PRINT #2, WP(WC%,1), WP(WC%,0);
```

The actual sorting routine which does the rearrangement is in the ORDER PROCedure which is only reached if a match is found.

```
210 ORDER
```

The SORT loop performs a simple exchange sort (see **Flowchart 3.8**). It takes the sentence position (IS%) of the first word found (first element in the first dimension, WP(0,0)) and compares it with the sentence position (IS%) of the second word found (second element in the first dimension, WP(0+1,0)). If the position variable for the first word is of higher value than that for the second word then the first word found is farther along the sentence than the second word, and these therefore need to be exchanged by swapping through a dummy variable (D%). This will put the sentence position pointers right, but the word count markers also need to be rearranged to the correct positions. This process is repeated until the word pointers are all in the correct order. Notice that the actual contents of the string array which holds the words are not altered but only the pointers (index) to them.



Flowchart 3.8: Putting Words in Order.

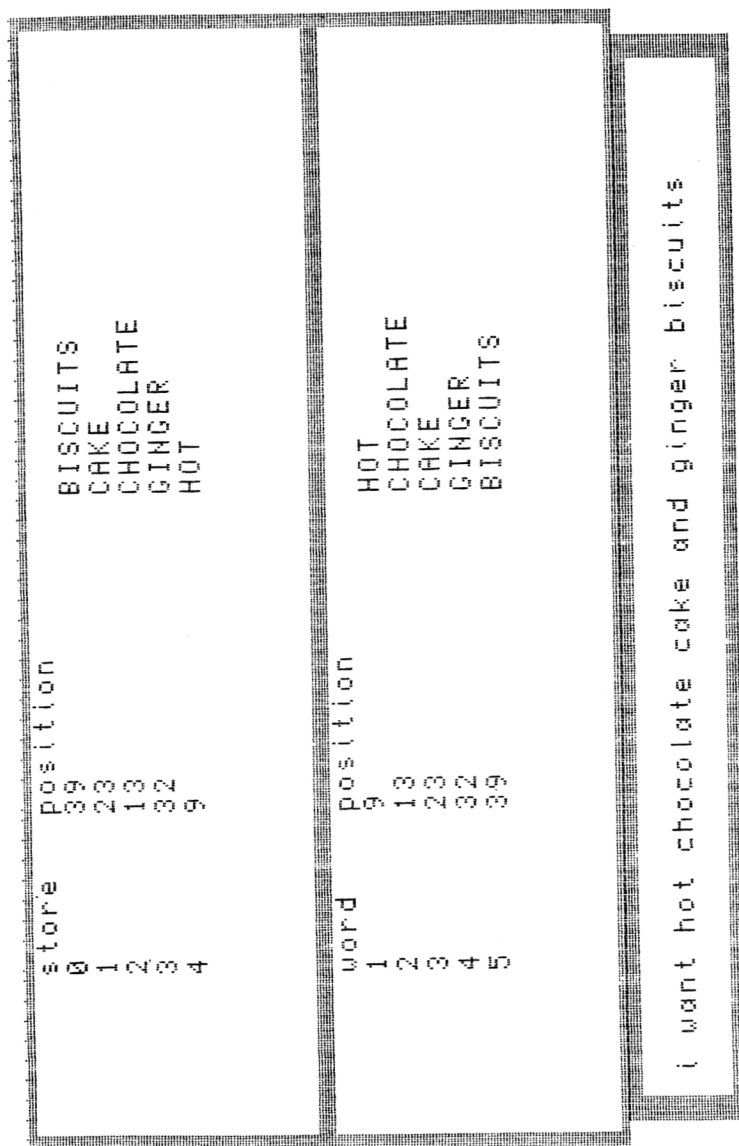


Figure 3.1: Sort.

```

100 PRINT #2, "store", "position"

2000 DEFine PROCedure ORDER
2010 REPeat SORT
2020 FOR N=0 TO WC%-1
2030 IF WP(N,0)>=WP(N+1,0) THEN
2040 D%=WP(N,0) : WP(N,0)=WP(N+1,0) :
      WP(N+1,0)=D%
2050 D%=WP(N,1) : WP(N,1)=WP(N+1,1) :
      WP(N+1,1)=D%
2060 END REPeat SORT
2070 END IF
2080 END FOR N
2090 END DEFine ORDER

```

If the strings are now printed in revised word count, WC%, order they will be as they were in the original sentence, which should make it easier to understand them.

```

220 FOR N=0 TO WC%
230 PRINT ,N+1,WP(N,0) , ,W$(WP(N,1))
240 END FOR N

```

If you RUN some test sentences you will be able to see the original position of the words in the store (top window) and the words then rearranged as in the sentence in the bottom window (see Figure 3.1).

## Chapter 4

# Making Reply

### More sensible replies

We have considered at length how to decode sentences which are typed into the computer, but the replies it has produced so far have been very limited and rigid. Although many of the original words in a sentence are often used in a reply, in a real conversation we look at the subject of the sentence and modify this word according to the context of the reply.

For example the input:

I NEED REST

might expect the confirmatory reply:

YOU NEED REST

and similarly:

YOU NEED REST

should generate:

I NEED REST

If you look at the situation logically you will realise that for each input subject there is an equivalent output subject, and that we have simply chopped off the original subject and added the remainder of the sentence to the appropriate new subject.

'I' is only a single character so we could check (IN\$(1)) and, if this was 'I', PRINT 'YOU' would be added to the front of the remainder of the input IN\$(2 TO).

```
10 SCREEN
20 REPEAT LOOP
30   AT #0, 1, 1 : IN$=GET$(1)
40   IN$=IN$ &" "
```

```

60     IF IN$(1)="I" THEN PRINT "YOU" &
      IN$(2 TO)
90     DUMMY$=INKEY$(500)
100    CLS #0
110    END REPEAT LOOP

```

(Note that the SCREEN format and the GET\$(1) routine are exactly the same as described for the last program.)

In the same way, the first three characters IN\$(1 TO 3) could be checked against 'YOU' and replaced when necessary by 'I':

```

80     IF IN$(1 TO 3)="YOU" THEN PRINT "I"
      & IN$(4 TO)

```

If you try that out with a series of sentences you will see that it works OK until you type something like:

YOU ARE TIRED

which comes back as the rather unintelligent:

I ARE TIRED

We could get around this by checking for the phrases 'I AM' and 'YOU ARE' as well as 'I' and 'YOU' on their own, but notice that you must test for these first and add NEXT LOOP to the end of lines 50 and 70 to prevent a match also being found with 'I' and 'YOU' alone.

```

50     IF IN$(1 TO 4)="I AM" THEN PRINT
      "YOU ARE" & IN$(5 TO) : NEXT LOOP
70     IF IN$(1 TO 7)="YOU ARE" THEN PRINT
      "I AM" & IN$(8 TO) : NEXT LOOP

```

### Wider dimensions

Although this method will work, the program soon gets very long-winded as a separate line is needed for each possibility as we must take into account the length of the matching word or phrase. Where many words are to be checked it is therefore better to use a multidimensional string array which can be compared with the input by a loop.

A convenient format is to have a two-dimensional array, I\$(N,M), where the first dimension of each element, I\$(N,0), is the input word or

phrase and the second dimension, I\$(N,1), is the corresponding output word or phrase. It is easier to avoid errors if these are entered into DATA in matching pairs and READ in turn into the array. Start a new program with these lines which SET\_UP the array.

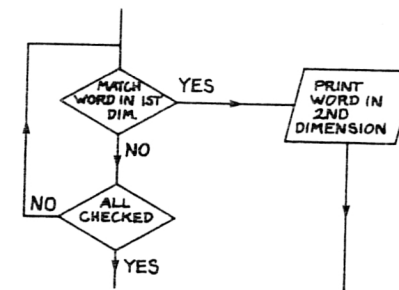
### 20 SET\_UP

```

11000 DEFINE PROCEDURE SET_UP
11010  RESTORE
11030  DIM I$(3,1,7)
11100  DATA "I AM","YOU ARE","YOU ARE","I AM"
11110  DATA "I","YOU","YOU","I"
11200  FOR N=0 TO 3
11210    READ I$(N,0) : READ I$(N,1)
11220  END FOR N
11390 END DEFINE SET_UP

```

We will use a looping sliding string search again, which for the moment will just print out the corresponding word or phrase to that matched, I\$(N,1) (see Flowchart 4.1). One advantage of the sliding string search here is that it will happily match embedded spaces in phrases as we have not broken IN\$ into 'words' before matching. (Note that the SCREEN format and the GET\$(1) routine are once again the same as described for the last program.)



Flowchart 4.1: Using a Corresponding Reply.

```

10 SCREEN
30 REPEAT IN
40   AT #0, 1, 1 : IN$=GET$(1)
50   IN$=IN$&" "
60   FOR M=0 TO 3

```



```

70      IS%=I$(M,0) INSTR IN$
80      IF IS%>0 THEN EXIT M
90      END FOR M
120     DUMMY$=INKEY$(500)
130     CLS #0
140     END REPEAT IN

```

The required response word is in the second dimension of the array (I\$(M,1)) so we PRINT this when the loop is left.

```

100     PRINT I$(M,1)

```

To get a fuller reply we need to add back on the rest of the original sentence (see **Flowchart 4.2**). It is not difficult to define the 'rest of the sentence' as we must simply subtract the matched word from the front of the sentence. IS% points to the start of the matched word, and we can easily find the LENGTH of this word as the word is stored in the first dimension of the array as I\$(M,0). We therefore need to add IN\$(IS%+LEN(I\$(M,0))) on to the front of our response word. To make clear what is happening, the individual parts of the reply are printed separately in the upper window.

```

100     PRINT #2, I$(M,1), IN$(IS%+LEN(I$(M,0)
      )) TO )
110     PRINT I$(M,1) & IN$(IS%+LEN(I$(M,0)))
      TO )

```

Now when you try:

I AM CLEVER

the computer agrees:

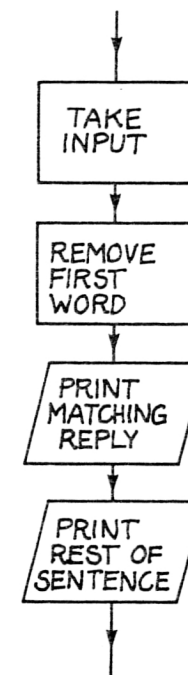
YOU ARE CLEVER

Before you feel too clever try:

WE ARE STUPID

which may well surprise you when it gives the reply:

YOUD (!!!)



Flowchart 4.2: A Fuller Reply.

If you think for a few moments you will see that one of our keywords is hiding inside another word in this particular sentence. If you cannot see it then try:

WE ARE INCOMPETENT

where the computer returns:

YOUNCOMPETENT

Although the keywords are tested for in turn, we EXIT the loop when a match is found so only the first match is reported. As the keyword is only checked for once in each sentence, embedded 'I' only causes problems when it precedes the keyword or there is no keyword in the sentence.

To get around this we must consider which keywords may cause problems. Although the letter 'I' is very common it is very rarely the last letter in a word, and so we could check that there is a space after the keyword. We must treat all keywords in the same way so add a space to

the end of them all. This can be done by changing the DATA. Note that there is no need to add spaces on to the end of the replies.

```
11100 DATA "I AM ", "YOU ARE", "YOU ARE ", "I AM"
11110 DATA "I ", "YOU", "YOU ", "I"
```

We now need to subtract one less character from IN\$, as a space has been included as part of the keywords.

```
110 PRINT I$(M,1) & IN$(IS%+LEN(I$(M,0))
    -1 TO )
```

The computer will now readily agree on your incompetence.

If the first key is not at the start of the sentence then everything before it will be ignored in the reply. For example the answer to:

WHAT IF I FALL?

will be:

YOU FALL?

Some strange results can still occur when two true keywords are present. For example:

WHAT IF YOU AND I FALL

gives

YOU FALL

and

WHAT IF I AND YOU FALL

replies

YOU AND YOU FALL

However adding more suitable keywords is easy and some combinations will just not be acceptable. To make the routine more general it is better to define the number of keywords as a variable, KW%, and use this in place of the actual number.

```
60 FOR M=0 TO 3
```

```
11020 KW%=5
11030 DIM I$(KW%,1,7)
11120 DATA "WE ", "WE", "THEY ", "THEY"
11200 FOR N=0 TO KW%
```

Now the answer to:

WHAT IF WE FALL?

is the more logical

WE FALL

### Pointing to replies

So far our computer has displayed only slightly more intelligence than a parrot as it has merely regurgitated a slightly modified version of the input. The next stage, therefore, is to make it take some logical decisions on the basis of the input before it replies.

The numbers of subjects, SU%, verbs, VB%, and replies, RP%, are defined as variables so that the program can be easily expanded, and three arrays using these are set up. (As we have a zero element in the array these values are all one less than the number of words.) S\$(n,n) is a two-dimensional array which is concerned with the subjects in the input and output sentences. The first dimension, (n,0) contains the recognised subject words and phrases allowed in the input, and the second dimension (n,1) contains the opposites which may be needed in the output. V\$(n) holds the legal verbs, and R\$(n) a series of corresponding replies.

```
10 SCREEN
20 SET_UP
```

```
11000 DEFine PROCedure SET_UP
11010 RESTORE
11020 SU%=26 : VB%=6 : RP%=6
11030 DIM S$(SU%,1,7) : DIM V$(VB%,7) :
    DIM R$(RP%,50)
```

The first six lines of DATA contain paired input and output subjects (see Table 4.1) and these are READ into corresponding dimensioned

Table 4.1: Pairs of Subjects in S\$(n,n).

S\$(n,0)	S\$(n,1)
I HAVE	YOU HAVE
I'VE	YOU'VE
I AM	YOU ARE
I'M	YOU'RE
YOU HAVE	I HAVE
YOU'VE	I'VE
YOU ARE	I AM
YOU'RE	I'M
YOU	I
SHE HAS	SHE HAS
SHE IS	SHE IS
SHE'S	SHE'S
SHE	SHE
THEY'VE	THEY'VE
THEY ARE	THEY ARE
THEY'RE	THEY'RE
THEY	THEY
HE HAS	HE HAS
HE IS	HE IS
HE'S	HE'S
HE	HE
WE HAVE	WE HAVE
WE'VE	WE'VE
WE ARE	WE ARE
WE'RE	WE'RE
WE	WE
I	YOU

elements in the S\$(n,n) array. As the pronouns ('I', 'YOU', etc) are frequently linked to other words to form phrases (such as 'I'VE') these combined forms are also included in the DATA. Notice that these are arranged in such an order that the most complete phrase containing a keyword is always found first. A space is added on to the end of each element, so that some clashing of partial matches is avoided and a space is automatically formed in the reply.

```
11040 DATA "I HAVE ", "YOU HAVE ", "I'VE ",
        "YOU'VE ", "I AM ", "YOU ARE ", "I AM ",
        "YOU'RE ", "YOU HAVE ", "I HAVE "
```

```
11050 DATA "YOU'VE ", "I'VE ", "YOU ARE ",
        "I AM ", "YOU'RE ", "I'M ", "YOU ", "I "
11060 DATA "SHE HAS ", "SHE HAS ", "SHE IS "
        "SHE IS", "SHE'S", "SHE'S", "SHE", "SHE"
11070 DATA "THEY'VE ", "THEY'VE ", "THEY ARE "
        "THEY ARE ", "THEY'RE ", "THEY'RE ",
        "THEY ", "THEY "
11080 DATA "HE HAS ", "HE HAS ", "HE IS ", "HE "
        "IS ", "HE'S ", "HE'S ", "HE ", "HE ", "WE "
        "HAVE ", "WE HAVE "
11090 DATA "WE'VE ", "WE'VE ", "WE ARE ", "WE "
        "ARE ", "WE'RE ", "WE'RE ", "WE ", "WE ", "I "
        "YOU "
```

```
11140 FOR N=0 TO SU%
11150 READ S$(N,0) : READ S$(N,1)
11160 END FOR N
```

The next DATA line contains the main verbs which are READ into VB%\$(n). The verb 'to be' is omitted as its variations are so complicated, and many of its versions are already accounted for in the 'subject' check.

```
11100 DATA "HATE", "LOVE", "KILL", "DISLIKE",
        "LIKE", "FEEL", "KNOW"
```

```
11170 FOR N=0 TO VB%
11180 READ V$(N)
11190 END FOR N
```

The last set of DATA contains the replies which are put into R\$(n), before control returns to the main part of the program. To make things simple to understand and check at this stage, all the replies contain the original verb, although of course they could say anything.

```
11110 DATA "PROBABLY HATE YOU AS WELL", "LOVE "
        "YOU TOO"
11120 DATA "KILL YOU", "DISLIKE LOTS OF THINGS"
11130 DATA "LIKE CHIPS", "FEEL POWERFUL?", "KNOW "
        "EVERYTHING"
11200 FOR N=0 TO RP%
11210 READ R$(N)
11220 END FOR N
11230 END DEFine SET_UP
```

## Matching

The input string is now compared with the list of subjects in the first dimension of  $SS(n,n)$  (see **Flowchart 4.3**). If there is no `SUB_MATCH` then the `NEXT IN` is requested, or else a subject match variable, `SM%`, is set to the element number at which a match was found. (The fact that no subject was found will be indicated by the fact that the input window (#0) does not clear before the next input.)

```

30  REPEAT IN
40  AT #0, 1, 1 : IN$=GET$(1)
50  IN$=IN$ & " "
60  SUB_MATCH
90  DUMMY$=INKEY$(500)
100 CLS#0
110 END REPEAT IN

1000 DEFINE PROCEDURE SUB_MATCH
1010 FOR M=0 TO SU%
1020 IS%=S$(M,0) INSTR IN$
1030 IF IS%>0 THEN
1050 SM%=M
1060 RETURN
1070 END IF
1090 END FOR M
1100 NEXT IN
1110 END DEFINE SUB_MATCH

```

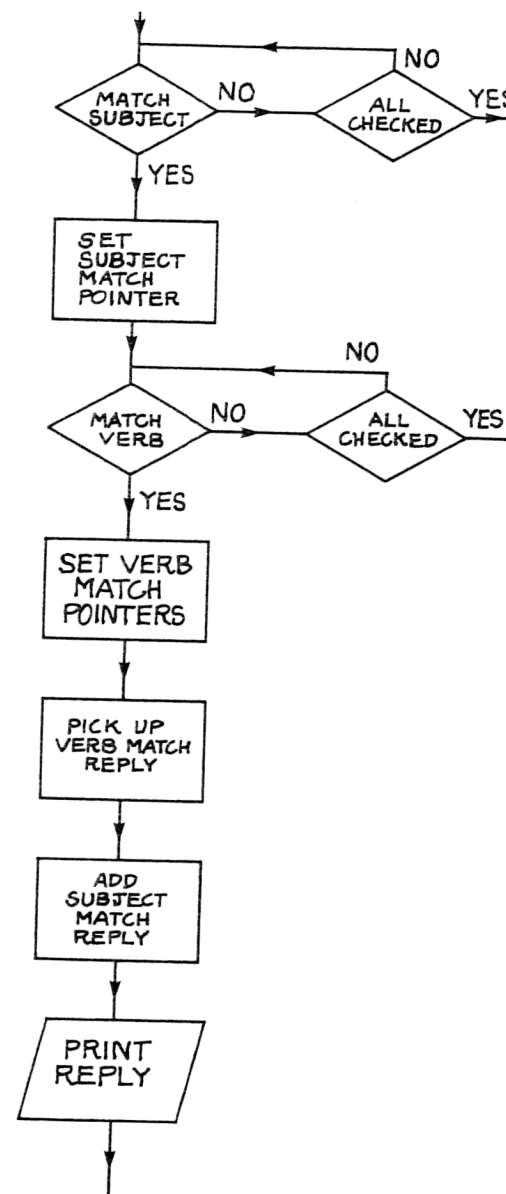
The verb array is now compared with `IN$`. If no verb is found then the input is rejected, or else the `VERB_MATCH` variable, `VM%`, is set.

```

70  VERB_MATCH

2000 DEFINE PROCEDURE VERB_MATCH
2010 FOR M=0 TO VB%
2020 IS%=V$(M) INSTR IN$
2030 IF IS%>0 THEN
2040 VM%=M
2060 RETURN
2070 END IF
2080 END FOR M
2090 NEXT IN
2100 END DEFINE VERB_MATCH

```



Flowchart 4.3: Setting Match Pointers.

**Making reply**

Now that the subject and verb have been identified, we can pick up the appropriate reply by using VM% as a pointer to the reply array, R\$(n).

```

80      REPLY

3000 DEFine PROCedure REPLY
3010   RL$=R$(VM%)

```

In the simplest case we can just add the appropriate subject to the front of RL\$ before we print it.

```

3060   RL$=S$(SM%,0) & RL$
3150   PRINT RL$
3190 END DEFine REPLY

```

Now, for example, if you type in:

I HATE COMPUTERS

the program will reply with

I PROBABLY HATE YOU AS WELL

and:

I KNOW A LOT

generates:

I KNOW EVERYTHING

**Alternative subjects**

If you prefer the machine to agree with you rather than trying to beat you at your own game, then just change the subject added to RL\$ to the second element of the array (the 'opposite').

```

3060   RL$=S$(SM%,1) & RL$

```

Now:

I KNOW A LOT

generates:

YOU KNOW EVERYTHING

For more variety you can pick the subject at random from the first or second element, so that the reply is not predictable.

```

3060   RL$=S$(SM%,RND(1)) & RL$

```

**Putting the subject in context**

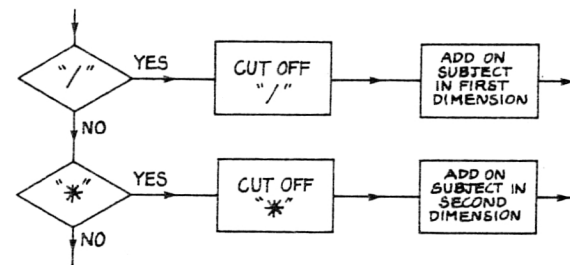
It would be more sensible altogether if we chose the correct subject according to the context of the reply, but to do that we must have markers in the reply array. We will use a slash sign, '/', to indicate that the word in the first dimension of the subject array is to be used, and an asterisk '\*' to indicate that the word in the second dimension is to be used.

```

11110  DATA "/PROBABLY HATE YOU AS WELL",
        "/LOVE YOU TOO"
11120  DATA "/KILL YOU","*DISLIKE LOTS OF
        THINGS"
11130  DATA "/LIKE CHIPS","*FEEL POWERFUL"
        ,"*KNOW EVERYTHING"

```

We can search the reply string, R\$(VM%), pointed to by the verb marker, VM%, for a slash sign, '/'. If a slash sign is found then the contents of the first dimension of the subject array, S\$(SM%,0), are added to the reply, RL\$, less the first character (the slash sign, see Flowchart 4.4).



Flowchart 4.4: Putting the Subject in Context.

```

3000 DEFine PROCedure REPLY
3010   RL#=R$(VM%)
3030   PRINT #2, RL$
3040   IS%="/" INSTR RL$
3050   IF IS%>0 THEN
3060     RL#=S$(SM%,0) & RL$(IS%+1 TO )
3080   END IF

```

If no slash sign is found in the reply, a second search is made for an asterisk, '\*'. If this is found then the second dimension of S\$(n,n) is used in the same way.

```

3090   IS%="*" INSTR RL$
3100   IF IS%>0 THEN
3110     RL#=S$(SM%,1) & RL$(IS%+1 TO )
3130   END IF
3150   PRINT RL$
3190 END DEFine REPLY

```

Now:

I LOVE ME

will give:

I LOVE YOU TOO

but:

I FEEL POWERFUL

produces:

YOU FEEL POWERFUL

### Inserting into sentences

To make things simple we have always started our reply sentences with the subject, but in real life this is not always the case. Now that we have markers in the replies to indicate what type of subject is to be added, we can also use them to indicate where in the reply to insert this word or phrase. First we will amend the DATA so that the word to be inserted is never at the start, to make the insertion process obvious.

```

11110 DATA "DO YOU REALISE THAT /PROBABLY
        HATE YOU AS WELL", "WELL /LOVE YOU TOO"
11120 DATA "IF /DON'T KILL YOU FIRST", "SO
        WHAT /DISLIKE LOTS OF THINGS ESPECIALLY
        * "
11130 DATA "DO /LIKE CHIPS", "WHY DO *FEEL
        POWERFUL?", "*THINK *KNOW EVERYTHING"

```

(Note that the space after the asterisk in the DISLIKE reply is essential as a marker must not be the last character in a reply string.)

We actually already have a record of where to insert the word as IS% tells us where in the reply the slash or asterisk was found. All we need to do is to take the part of the reply before the marker (RL\$(1 TO IS%-1)), add the correct version of S\$(SM%,n), and then the rest of the reply (RL\$(IS%+1 TO)).

```

3060     RL#=RL$(1 TO IS%-1) & S$(SM%,0)
        & RL$(IS%+1 TO )

```

```

3110     RL#=RL$(1 TO IS%-1) & S$(SM%,1)
        & RL$(IS%+1 TO )

```

Now:

I WILL KILL HIM

produces:

IF I DON'T KILL YOU FIRST

and:

I DISLIKE COMPUTERS

gives:

SO WHAT YOU DISLIKE LOTS OF THINGS

Although we are now inserting the subject into the reply sentence more naturally, we are only dealing with one subject per sentence. Some more minor modifications will allow us to insert any number of subjects into a sentence.

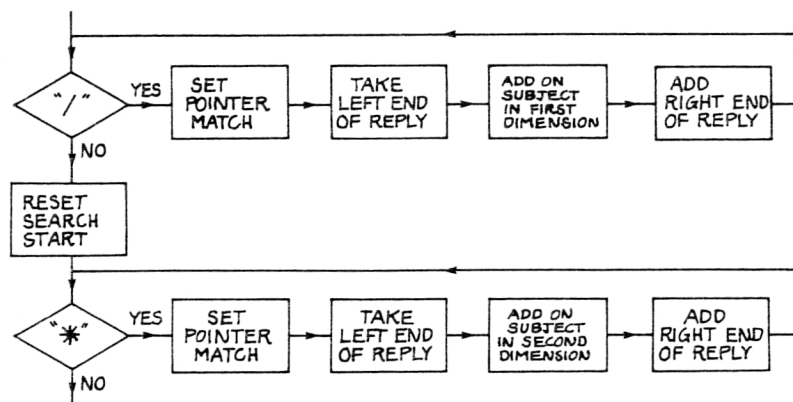


```

11120 DATA "IF /DON'T KILL YOU FIRST", "SO
      WHAT /DISLIKE LOTS OF THINGS ESPECIALLY
      $ "
11130 DATA "DO /LIKE CHIPS", "WHY DO *FEEL
      POWERFUL?", "*THINK *KNOW EVERYTHING"

```

We need to define the initial reply (RL\$) as RS\$(VM%) and then REPEAT the CHECK for markers until no more are found (IS% = 0) when we EXIT the CHECK loop (Flowchart 4.5).



Flowchart 4.5: Inserting into a Sentence.

```

3000 DEFine PROCedure REPLY
3010   RL$=R$(VM%)
3020   REPEAT CHECK
3030     PRINT #2,RL$
3040     IS%="/" INSTR RL$
3050     IF IS%>0 THEN
3060       RL$=RL$(1 TO IS%-1) & S$(SM%,0)
          & RL$(IS%+1 TO )
3070     NEXT CHECK
3080     END IF
3090     IS%="*" INSTR RL$
3100     IF IS%>0 THEN
3110       RL$=RL$(1 TO IS%-1) & S$(SM%,1)
          & RL$(IS%+1 TO )
3120     NEXT CHECK
3130     END IF

```

```

3140       IF IS%=0 THEN
3150         PRINT RL$
3160       EXIT CHECK
3170       END IF
3180     END REPEAT CHECK
3190 END DEFine REPLY

```

Now:

I KNOW EVERYTHING

produces:

YOU THINK YOU KNOW EVERYTHING

and:

I DISLIKE COMPUTERS

gives

SO WHAT I DISLIKE LOTS OF THINGS ESPECIALLY YOU

### OBJECTIONs on the SUBJECT

Everything is starting to look rosy until you try something like:

I HATE YOU

which replies

DO YOU REALISE THAT YOU PROBABLY HATE YOU AS WELL

The problem here is that we are jumping out of the search routine as soon as the first match is found, and that although we are checking for the subject 'I' we are finding the object 'YOU' first. As 'YOU' comes before 'I' in the subject array this is found first, in spite of the fact that it comes later in the sentence.

As we cannot practically mimic all the intricacies of the human brain we will have to make the assumption that the subject always comes before the verb, and the object after it. In the program so far we have been checking for the subject before we checked for the verb, so we will have to reverse that order.

```

60   VERB_MATCH
70   SUB_MATCH

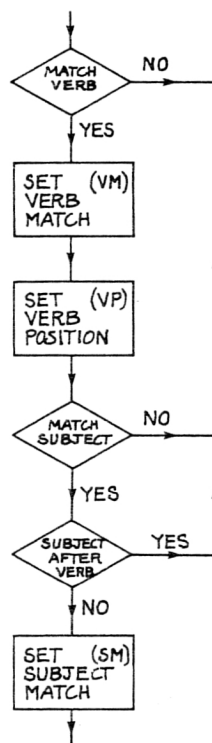
```

The verb position in the input is the value of IS% when a verb is found, so we will save that as a verb position, VP%, pointer.

```

2000 DEFine PROCedure VERB_MATCH
2010   FOR M=0 TO VB%
2020     IS%=V$(M) INSTR IN$
2030     IF IS%>0 THEN
2040       VM%=M
2050       VP%=IS%
2060       RETURN
2070     END IF
2080   END FOR M
2090 END DEFine VERB_MATCH

```



Flowchart 4.6: Rejecting Object Matches.

Now when a match with the subject array is found we can compare that position, IS%, with the stored verb pointer, VP%, and reject the match if the match is positioned after the verb (see Flowchart 4.6).

```

1000 DEFine PROCedure SUB_MATCH
1010   FOR M=0 TO SU%
1020     IS%=S$(M,0) INSTR IN$
1030     IF IS%>0 THEN
1040       IF IS% < VP% THEN
1050         SM%=M
1060         RETURN
1070       END IF
1080     END IF
1090   END FOR M
1100   NEXT IN
1110 END DEFine SUB_MATCH

```

### A change of tense

Although both 'LIKE' and 'DISLIKE' contain the sequence 'L-I-K-E', we find 'DISLIKE' correctly as it is before 'LIKE' in the array. But if we change to the past tense of the verb it may or may not be found. With the first five verbs the situation is straightforward as to change to the past tense we just add on a 'D' at the end of the present tense. Both forms are therefore accepted.

HATE	HATED
LOVE	LOVED
KILL	KILLED
DISLIKE	DISLIKED
LIKE	LIKED

However, with the last two verbs the word changes completely, so there can be no simple match. Although we might get away with checking for 'KN', as this is a rare combination, there is no practical way we can use such a common group as 'FE' as a keyword.

FEEL	FELT
KNOW	KNEW

It is easier if we treat all verbs in the same way and, if there are no

constraints on memory, then we can simply put all the possible versions into the verb array in pairs.

```
11020  SU%=26 : VB%=13 : RP%=6
11100  DATA "HATE", "HATED", "LOVE", "LOVED",
        "KILL", "KILLED", "DISLIKE", "DISLIKED"
11105  DATA "LIKE", "LIKED", "FEEL", "FELT",
        "KNOW", "KNEW"
```

Unless we want to have different replies for the different tenses, we will now have to divide the verb match variable, VM%, by two, to point to the correct reply for both forms.

```
2040      VM%=INT (M/2)
```

## CHAPTER 5

### Expert Systems

A human expert is someone who knows a great deal about a particular subject and who can give you sensible advice ('expert opinion') on it. Such expertise is only acquired after long training and a great deal of experience, so unfortunately real experts are few and far between. In addition they are often not on hand when a problem needs to be solved.

Scientists have therefore applied themselves to the problem of producing computer programs which mimic the functions of such human experts. Such programs have the advantage that they can be copied very easily to produce an infinite number of experts, and of course they do not need tea-breaks, sleep, pay-rises, etc, either! Of course the computer must be totally logical and can still only follow pre-programmed instructions entered by the programmer. It is interesting to note that science fiction authors have envisaged problems when the ultimate experts (such as HAL in '2001: A Space Odyssey' or Isacc Asimov's positronic robots) are faced with alternative courses which conflict with more than one of their prime directives and produce not system crashes but 'pseudo-nervous breakdowns'.

Before we can start writing programs for expert systems we must ask ourselves how a human expert works.

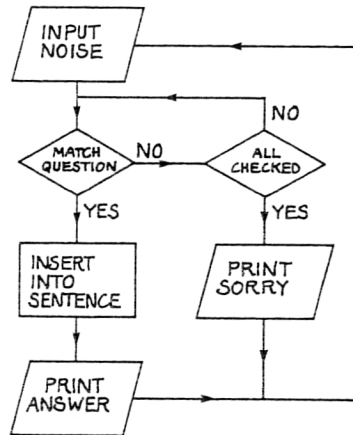
Let us first consider the simplest situation where the expert's task is to find the answer to a known problem.

First of all he takes in information on the current task

Secondly he compares this with information stored in his brain and looks for a match

Finally he reports whether a match has been found or not

What we need here is simply a database program which tries to match the input against stored information (see **Flowchart 5.1**). A user-friendly system would accept natural language (see earlier) but to keep things simple here we will stick to a fixed input format. To start with, let's look at recognising animals by the sounds they make. We use a START PROCedure to set up two arrays: the question array, QU\$(n), contains



Flowchart 5.1: A Simple 'Expert'.

the sounds which are known, and each element of the answer array, `ANS(n)`, contains the name of the relevant animal.

```
10 SCREEN
20 START
```

```
10000 DEFine PROCedure SCREEN
10010  MODE 4
10020  CLS #0 : CLS #1 : CLS #2
10030 END DEFine SCREEN

11000 DEFine PROCedure START
11010  RESTORE
11020  DIM QU$(4,5),ANS$(4,5),IN$(5)
11030  DATA "MIAOW","CAT","WUFF","DOG","MOO"
11040  , "COW","HOOT","OWL","NEIGH","HORSE"
11040  FOR N=0 TO 4
11050    READ QU$(N) : READ AN$(N)
11060  END FOR N
11070 END DEFine START
```

Now we just need to ask for a sound, using our `GET$(1)` FuNction, and compare it with the contents of `QU$(n)`. If a match is found then an `ANSWER PROCedure` is called.

```
30 REPEAT QUESTION
40 PRINT\ "WHAT NOISE DOES IT MAKE? ";
50 IN$=GET$(1)
60 FOR N=0 TO 4
70 IF IN$=QU$(N) THEN ANSWER
80 END FOR N
90 PRINT "SORRY I DON'T KNOW THAT ONE"
100 END REPEAT QUESTION
```

```
12000 DEFine PROCedure ANSWER
12010 PRINT "AN ANIMAL THAT ";QU$(N); "S IS
A ";ANS$(N)
12020 END REPEAT QUESTION
12030 END DEFine ANSWER
```

Perhaps we should say at this point that our computer expert may well be better at this task than the human as it cannot make subjective judgements, become bored, or accidentally forget to check all of the information in its memory. On the other hand it is not very literate as it reports 'A OWL', etc. (We will leave you to tidy that up by adding a routine which checks whether the first letter of the answer array match is a vowel.)

### Branching out

The example above is very simple as only one question is asked, and there is only one possible answer. In reality we need to be able to deal with more difficult problems, where the answer cannot be found without asking a whole series of questions. For example what should an expert do if he put the key in the ignition switch of his car and turned it, but nothing happened?

There could be a number of reasons for this:

```
FLAT BATTERY
BAD CONNECTIONS
SWITCH BROKEN
STARTER JAMMED
STARTER BROKEN
SOLENOID BROKEN
```

To find the cause he should follow a logical path and make a number of checks. The first thing to do is to check whether it is only the starter motor which is not working?

## IS IGNITION LIGHT ON? (Y/N)

If the answer to this is 'N' then there is no power at the switch, so the cause must be one of the first three possibilities listed above. We can narrow things down more by finding out if the lights work:

## DO LIGHTS WORK CORRECTLY? (Y/N)

If the answer is yes then the battery cannot be flat, and it must be connected to the light switch correctly, so presumably the switch is broken and a suggestion can be made that you replace it.

## REPLACE IGNITION SWITCH

If the lights do not work then the connections should be checked.

## ARE BATTERY CONNECTIONS OK? (Y/N)

If the answer is yes then the battery is flat so you must charge it (or push!).

## CHARGE BATTERY OR PUSH CAR

In the same way a sequence of checks could be made to deal with the situation where there is power but the starter mechanism itself does not work (the last three possibilities). The simplest way to program this branching structure is a series of IF-THEN tests which call the appropriate PROCedures according to your response (see Flowchart 5.2).

```

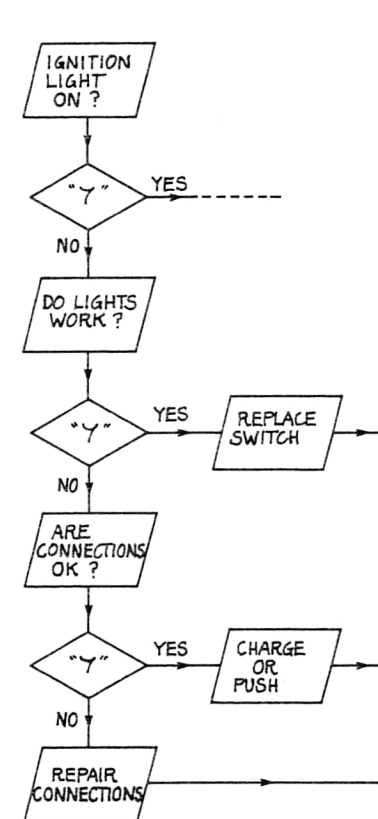
10 SCREEN
20 START

10000 DEFine PROCedure SCREEN
10010  MODE 4
10020  CLS #0 : CLS #1 : CLS #2
10030 END DEFine SCREEN

11000 DEFine PROCedure START
11010  PRINT "\"FAULT DIAGNOSIS"
11020  IGNITION
11030 END DEFine START

12000 DEFine PROCedure IGNITION

```



Flowchart 5.2: A Branching 'Expert'.

```

12010  PRINT "\"IS IGNITION LIGHT ON (Y/N) ";
12020  IN$=GET$(1)
12030  IF IN$="Y" THEN REST
12040  LIGHTS
12050 END DEFine IGNITION

13000 DEFine PROCedure LIGHTS
13010  PRINT "\"DO LIGHTS WORK CORRECTLY (Y/N)";
13020  IN$=GET$(1)
13030  IF IN$="Y" THEN BATTERY
13040  PRINT "\"REPLACE IGNITION SWITCH "
13050  START
13060 END DEFine LIGHTS

```

```

14000 DEFine PROCedure BATTERY
14010 PRINT "\"ARE BATTERY CONNECTIONS OK
      (Y/N)";
14020 IN$=GET$(1)
14030 IF IN$="Y" THEN CHARGE
14040 PRINT "\"REPAIR CONNECTIONS "
14050 START
14060 END DEFine BATTERY

15000 DEFine PROCedure CHARGE
15010 PRINT "\"CHARGE BATTERY OR PUSH CAR "
15020 START
15030 END DEFine CHARGE

16000 DEFine PROCedure REST
16010 STOP
16020 END DEFine REST

```

This sort of program is relatively easy to write, but as usual is inefficient as it becomes longer and more complicated.

### Pointing the way

A more efficient way to deal with the situation is to put the text into arrays and have pointers which direct you to the next question or reply, according to whether you answer yes or no to the current question (see **Flowchart 5.3**).

The format for entering the DATA for each branch point is then:

(TEXT), (pointer for 'YES'), (pointer for 'NO')

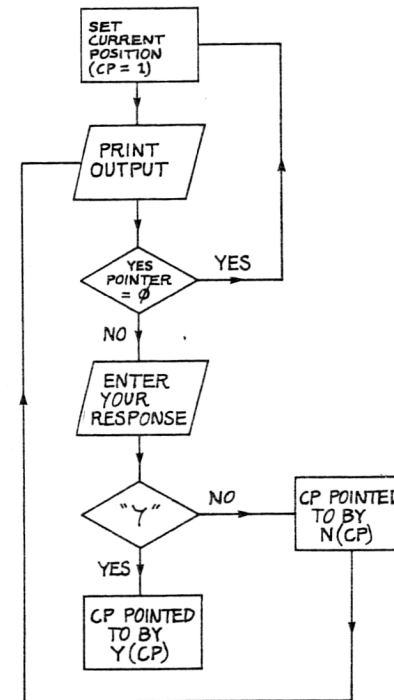
The first question was:

IS IGNITION LIGHT ON? (Y/N) . . . . 1

If the answer was 'N' then you need to ask the second question:

DO LIGHTS WORK CORRECTLY? (Y/N) . . . . 2

Otherwise you need to continue with the other part of the diagnosis (which we have not included but which would be point 7). We need to set up three arrays: OP\$(n) contains the output (text), Y(n) the pointer for 'yes', and N(n) the pointer for 'no'. To make the program easy to modify



Flowchart 5.3: Pointing to the Next Output.

a variable, NP%, is used for the number of points. The DATA is read in groups of three into each element in these arrays. Where the DATA point is a possible end of the program this is indicated by the Y(n) and N(n) pointers being set at zero. (Note that the SCREEN PROCedure is the same as in the last program, but that the rest of the program is new.)

```

10 SCREEN
20 START

```

```

11000 DEFine PROCedure START
11010 RESTORE
11020 NP%=7 : DIM OP$(NP%,30),Y(NP%),N(NP%)
11030 DATA "IS IGNITION LIGHT ON",7,2
11040 DATA "DO LIGHTS WORK CORRECTLY",3,4
11050 DATA "REPLACE SWITCH",0,0
11060 DATA "ARE BATTERY CONNECTIONS OK",5,6
11070 DATA "CHARGE BATTERY OR PUSH CAR",0,0

```



```

11080 DATA "REPAIR CONNECTIONS",0,0
11090 DATA "rest of program",0,0
11100 FOR M=1 TO NP%
11110 READ OP$(M) : READ Y(M) : READ N(M)
11120 END FOR M
11130 END DEFine START

```

The actual running routine is very simple. A pointer, CP%, is used to indicate the current position in the array: to begin with this is set to 1, and the first text pointed. If this is an end point, Y(CP%) = 0, (hardly likely just yet!) then we EXIT QUESTION and CP% is reset to 1 when the sequence is RESTARTed. If a real pointer is present then the REPEAT QUESTION loop requests an INPUT. If the input is 'Y' then CP% is set to the value contained in the appropriate element of the Y(n) array, otherwise it is set to the value contained in the N(n) array.

```

30 REPEAT RESTART
40 UNDER 1 : PRINT "\"FAULT DIAGNOSIS"
   : UNDER 0
50 CP%=1
60 REPEAT QUESTION
70 PRINT \OP$(CP%)," ";
80 IF Y(CP%)=0 THEN EXIT QUESTION
90 IN$=GET$(1)
100 IF IN$="Y" THEN CP%=Y(CP%) :
    NEXT QUESTION
110 CP%=N(CP%)
120 END REPEAT QUESTION
130 END REPEAT RESTART

```

### A parallel approach

An alternative to the sequential branching method described above is the parallel approach which always asks all the possible questions before it reaches its conclusion. This method usually takes longer than following an efficient tree structure but it is more likely to produce the correct answer as no points of comparison are omitted.

Let us consider how we might distinguish between various forms of transport.

We will consider eight features and mark 1 or 0 for the presence or absence of these in each of our five modes of transport (Table 5.1). If you look closely you will notice that the pattern of results varies for each of the

different possibilities, so it must be possible to distinguish between them by these features.

Table 5.1: Presence or Absence of Features.

	bicycle	car	train	plane	horse
wheels	1	1	1	1	0
wings	0	0	0	1	0
engine	0	1	1	1	0
tyres	1	1	0	1	0
rails	0	0	1	0	0
windows	0	1	1	1	0
chain	1	0	0	0	0
steering	1	1	0	1	1

We will enter these values as DATA and then READ them into a two-dimensional array, FE(n,n), which will hold a copy of this pattern, together with a string array containing the names of the objects OB\$(n). (Note that SCREEN is as before.)

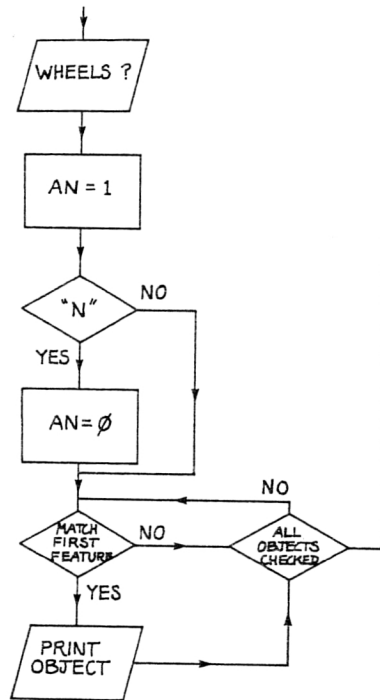
```

10 SCREEN
20 START

11000 DEFine PROCedure START
11010 RESTORE
11020 DIM OB$(5,7),FE(5,8)
11030 DATA "BICYCLE",1,0,0,1,0,0,1,1
11040 DATA "CAR",1,0,1,1,0,1,0,1
11050 DATA "TRAIN",1,0,1,0,1,1,0,0
11060 DATA "PLANE",1,1,1,1,0,1,0,1
11070 DATA "HORSE",0,0,0,0,0,0,0,1
11080 FOR N=1 TO 5
11090 READ OB$(N)
11100 FOR M=1 TO 8
11110 READ FE(N,M)
11120 NEXT M
11130 NEXT N
11140 END DEFine START

```

We can now QUESTION whether the first feature is present or not, and then CHECK which modes of transport match at this particular point (see Flowchart 5.4).



Flowchart 5.4: A Parallel Approach.

BICYCLE  
CAR  
TRAIN  
PLANE

and answering 'N' will produce a printout of only:

HORSE

This clearly demonstrates a possible disadvantage of the parallel method as, although we have just shown that only a horse does not have wheels, the program insists that we still ask all the other questions before it commits itself. This is not really as silly as it seems at first, as if you answer 'Y' to the next question ('does it have wings') then you will see that the computer quite logically refuses to believe in flying horses.

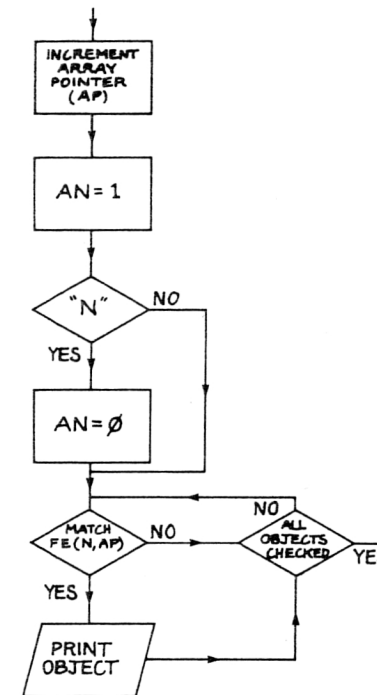
We can now use the comparison CHECK PROCedure to test for all eight features in turn. We need to make slight modifications, adding an array pointer, AP%, which is incremented to check the next element of the feature array, FE(N,AP%), in each cycle (see Flowchart 5.5).

```

30  REPEAT QUESTION
50  PRINT "\"DOES IT HAVE WHEELS ";
    : CHECK
250  END REPEAT QUESTION

12000 DEFINE PROCEDURE CHECK
12010  IN$=GET$(1)
12020  AN%=1
12030  IF IN$="N" THEN AN%=0
12040  FOR N=1 TO 5
12050    IF FE(N,1)=AN% THEN PRINT OB$(N)
12060  END FOR N
12070 END DEFINE CHECK
  
```

In this case, answering 'Y' will produce a printout of:



Flowchart 5.5: Checking the Features in Turn.

```

30 REPEAT QUESTION
50 PRINT "\"DOES IT HAVE WHEELS "; :
  CHECK
60 PRINT "\"DOES IT HAVE WINGS "; :
  CHECK
70 PRINT "\"DOES IT HAVE AN ENGINE "; :
  CHECK
80 PRINT "\"DOES IT HAVE TYRES "; :
  CHECK
90 PRINT "\"DOES IT NEED RAILS "; :
  CHECK
100 PRINT "\"DOES IT HAVE WINDOWS "; :
  CHECK
110 PRINT "\"DOES IT HAVE A CHAIN "; :
  CHECK
120 PRINT "\"IS IT STEERABLE "; :
  CHECK
130 AP%=0
250 END REPEAT QUESTION

11020 DIM OB$(5,7),FE(5,8) : AP%=0
12020 AP%=AP%+1 : AN%=1

12050 IF FE(N,AP%)=AN% THEN PRINT OB$(N)

```

### Top of the pops

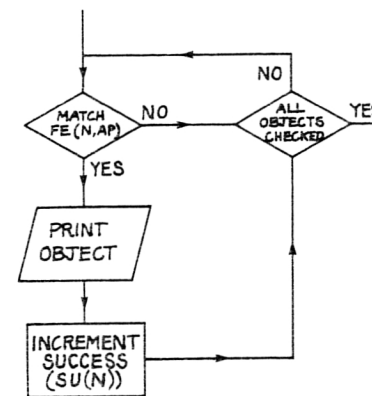
The previous routine will print out a list of matches for each individual question as it proceeds, but it does not actually tell us which set of DATA is an overall match for the answers to all the questions. We can produce a SCORE which shows how well the answers match the DATA by having a success array element, SU(n), for each object, which is only incremented when a match is found, FE(N,AP%) = AN% (see Flowchart 5.6).

```

200 PRINT "\"SCORE"
210 FOR N=1 TO 5
220 PRINT OB$(N),SU(N)
230 SU(N)=0
240 END FOR N

11020 DIM OB$(5,7),FE(5,8) : AP%=0 : DIM SU(5)
12050 IF FE(N,AP%)=AN% THEN PRINT OB$(N)
      : SU(N)=SU(N)+1

```



Flowchart 5.6: Measuring Success.

If a complete match is found then SU(n) will be equal to 8. Where one or more points was incorrect, the score will be lowered, but scoring in this way is particularly useful where the correct answers to the questions are more a matter of opinion than fact (eg is a horse really steerable?), as the highest score actually obtained probably points to the correct answer anyway. (Notice that in this case each correct answer has equal weighting.)

### Better in bits

You may have noticed that we just happened to use eight features for comparison and it may have occurred to you that this choice was not entirely accidental as there are eight bits in a byte. If we consider each feature as representing a binary digit (see Table 5.2), rather than an

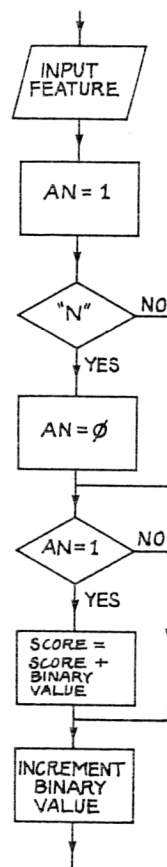
Table 5.2: Binary Weighted Features.

	bicycle	car	train	plane	horse
wheels	1	1	1	1	0
wings	0	0	0	2	0
engine	0	4	4	4	0
tyres	8	8	0	8	0
rails	0	0	16	0	0
windows	0	32	32	32	0
chain	64	0	0	0	0
steering	128	128	0	128	128
sum total	201	173	53	175	128

absolute value, then each object can be described by a single decimal number which is the sum of the binary digits, instead of eight separate values. We will convert to decimal with the least significant bit at the top so that starting from the top at 'wheels' each feature is equivalent to 1, 2, 4, 8, 16, 32, 64, 128 in decimal notation.

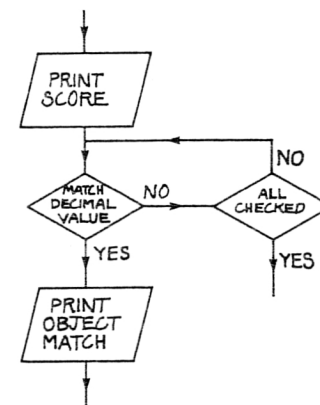
It is not too difficult to convert our 'score' of 1 to 8 into the appropriate binary value, as long as we remember that the decimal value of the binary digit, BV%, must double each time we move down and that we must only add the current binary value to the score if the answer was 'yes', AN% = 1 (see **Flowchart 5.7**).

If you consider for a moment, you will realise that we only need to keep track of the total number produced, SU%, by adding the binary values of the 'yes' answers — there is no need to loop through and check each part



Flowchart 5.7: Producing a Binary Score.

of the array contents each time, or even to have a two-dimensional array at all! The only DATA we need to enter are the overall decimal values for each object, DV(n), and when all the questions have been asked we can check these against the decimal value obtained by the binary conversion of the 'yes/no' answers, SU% (see **Flowchart 5.8**).



Flowchart 5.8: Matching the Decimal Value.

```

40  BV%=1 : SU%=0
220  IF DV(N)=SU% THEN PRINT ,OB*(N) :
      NEXT QUESTION
230  END FOR N
240  REMARK DELETED

11020 DIM OB*(5,7),DV(5)
11030 DATA "BICYCLE",201
11040 DATA "CAR",173
11050 DATA "TRAIN",53
11060 DATA "PLANE",173
11070 DATA "HORSE",128

11090 READ OB*(N)
11100 READ DV(N)
11110 REMARK DELETED
11120 REMARK DELETED

12040 IF AN%=1 THEN SU%=SU%+BV%
  
```

```
12050    BV%=BV%+BV%
12060    REMark DELETED
```

This approach obviously saves a lot of memory and time, as each array element takes up several bytes and must be located before it can be compared, so it is particularly useful where you are dealing with large amounts of information. But it does mean that you have to calculate the decimal equivalents of all of the bit patterns before you can use them, and it also gives you no clues when a complete match is not found. (Note that you cannot simply take the nearest decimal value here as the decimal equivalent value of each correct answer depends on its position.)

Of course you could do the calculations the hard way, but on the other hand you can easily DEFine a BIN FuNction to do the hard work for you. A row of eight dots is printed as a prompt and the required string of binary digits (N\$) entered, and passed to BIN. This slices off each individual digit, starting from the least significant (righthand end). If the digit is 1 (note that SuperBASIC coercion allows direct comparison of string and simple variables) then the decimal value (DV%) is updated. When all eight digits have been checked, the final decimal value (DV%) is RETurned.

```
1 CLS
2 PRINT "....."
3 INPUT N$
4 PRINT BIN(N$)
5 GO TO 2

30000 DEFine FuNction BIN(N$)
30010    DV%=0 : BD%=1
30020    FOR N=8 TO 1 STEP -1
30030        IF N$(N)=1 THEN DV%=DV%+BD%
30040        BD%=BD%*2
30050    END FOR N
30060    RETurn DV%
30070 END DEFine BIN
```

## CHAPTER 6

### Making your Expert System Learn for Itself

Although the expert systems described so far will function all right, they all require you to give them the correct rules on which to base their decisions in advance, which can be very tedious, or even downright impossible where the human expert is not really sure of the answer.

However it is also possible to construct an expert program which can learn from its mistakes and work out the decision rules for itself, which is, of course, what a human expert tends to do. The only requirement is that *you* have to tell it when (although not where) it goes wrong. This is obviously an advantage if you are not altogether sure of the correct rules yourself anyway. In this case we start out with a series of feature variables which we hope should enable us to distinguish between the different objects (outcomes) but without any predefined yes/no pattern of these features ('decision rule') to guide us. Instead we use the program itself to determine what the pattern should be.

We will work with our familiar transport example and start by setting up the variables. FE% is the number of features to be considered, 8, FE\$(N) is an array containing the names of these features, FV(N) is an array which will hold the values which you give to each feature when you make input at any particular point (as 0 or 1), and RU(N) is an array which will hold the current overall values of the decision rule on each feature.

```
10 SCREEN
20 START
```

```
10000 DEFine PROCedure SCREEN
10010    MODE 4
10020    CLS #0 : CLS #1 : CLS #2
10030 END DEFine SCREEN
```

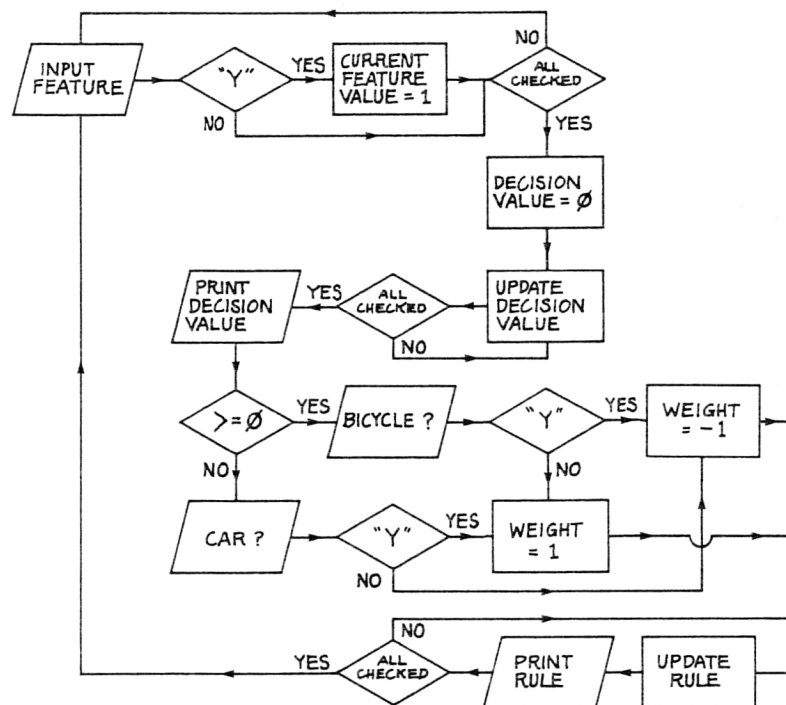
```
11000 DEFine PROCedure START
11010    RESTORE
11020    FE%=8 : DIM FE$(FE%,8),FV(FE%),RU(FE%)
```

```

11030   FOR N=1 TO FE%
11040     READ FE$(N)
11050   END FOR N
11060   DATA "WHEELS", "WINGS", "ENGINE", "TYRES",
          "RAILS", "WINDOWS", "CHAIN", "STEERING"
11070 END DEFine START

```

Each feature is considered in turn (see **Flowchart 6.1**) in the QUESTION PROCedure. First the current feature value, FV(N), for this cycle is set to 0, and then a 'yes/no' input IN\$ is requested from the user on each point. If IN\$ is 'Y', the feature value element, FV(N), is set to 1, but otherwise it remains set at 0. This will produce a pattern which describes the particular object (outcome) as a pattern of '0' and '1' in array FV(N).



Flowchart 6.1: Learning to Distinguish Between Two Objects.

```

50 REPEAT QUESTION
60   FOR N=1 TO FE%
70     FV(N)=0
80     PRINT !FE$(N);
90     IN$=INKEY$(-1)
100    IN$=CHR$((CODE(IN$) !! 32)-32)
110    IF IN$="Y" THEN FV(N)=1
120  END FOR N

```

200 END REPEAT QUESTION

(Note that a simpler method of forcing upper case is used here, rather than the GET\$ PROCedure, as only single character inputs are made which are easily modified.)

Now in UPDATE\_DE the decision variable, DE%, is set to zero before being recalculated as the sum of the current value of DE% plus each of the feature values, FV(N), entered multiplied by the current decision rule values, RU(N).

130 UPDATE=DE

```

12000 DEFine PROCedure UPDATE_DE
12010   DE%=0
12020   FOR N=1 TO FE%
12030     DE%=((DE%*3)+(FV(N)*RU(N))*3)/3
12040   END FOR N
12050   PRINT "\"DE%= ";DE%
12060 END DEFine UPDATE_DE

```

### Which is which?

To start with, we will consider the simplest situation where there are only two possibilities — a BICYCLE or a CAR. Initially we make the distinction between these quite arbitrarily by saying that if the final value of DE% is equal to or greater than 0 then it is a BICYCLE, whereas if DE% is less than 0 then it is a CAR. It does not really matter that this is not actually true as the system will soon correct itself. When the program has made a decision on the basis of the value of DE% it requests confirmation (or otherwise) of the result.

```

180   IF DE%>=0 THEN PRINT "\"IS IT A BICYCLE
      "; : IN$=INKEY$(-1) : IN$=CHR$((CODE(
      IN$) !! 32)-32) : PRINT IN$ : BICYCLE

```



```

190 IF DE%<0 THEN PRINT "\"IS IT A CAR "; :
    IN$=INKEY$(-1) : IN$=CHR$(CODE(IN$)
    || 32)-32) : PRINT IN$ : CAR

```

Three possible courses of action may be taken according to whether or not the computer's decision was confirmed by you.

If it was correct then effectively no action is taken as the weighting variable, WT%, is set to 0.

If DE% was  $\geq 0$ , but the computer was wrong (and selected CAR), then the weighting variable, WT%, is set to -1.

If DE% was  $< 0$ , but the computer was wrong (and selected BICYCLE), then WT% is set to +1.

```

13000 DEFine PROCedure BICYCLE
13010 IF IN$="Y" THEN WT%=0 : UPDATE_RULE
13020 WT%=-1 : UPDATE_RULE
13030 END DEFine BICYCLE

```

```

14000 DEFine PROCedure CAR
14010 IF IN$="Y" THEN WT%=0 : UPDATE_RULE
14020 WT%=1 : UPDATE_RULE
14030 END DEFine CAR

```

The effect of the weighting variable takes place in the UPDATE\_RULE PROCedure in which we modify the values in the rule array, RU(N), pulling them down when they are too high, and pulling them up when they are too low.

```

15000 DEFine PROCedure UPDATE_RULE
15010 PRINT "\"RULES\"\"
15020 FOR N=1 TO FE%
15030 RU(N)=(RU(N)*3)+(FV(N)*WT%)*3)/3
15040 PRINT RU(N),FE$(N)
15050 END FOR N
15060 END DEFine UPDATE_RULE

```

The way the system operates is best seen by a demonstration. Type RUN and then follow this sequence of entries. (Note that the punctuation has been designed to give a screen format which clearly indicates the relationship between your input values and the decision rule values.)

First of all enter these values:

```

WHEELS Y   WINGS N   ENGINE N   TYRES Y
RAILS N    WINDOWS N  CHAIN Y    STEERING Y

```

The program will return with a decision value, DE%, of 0, as this is the initial value and no modifications have yet taken place:

DE% = 0

As DE% is 0 then the system assumes that this is a BICYCLE and asks for confirmation, to which the answer is, of course, 'yes':

IS IT A BICYCLE? Y

The contents of the rule array, RU(N), are now printed out. This shows that the values have not changed from 0 as the correct answer was, by pure chance, obtained!

RULES

```

0          WHEELS
0          WINGS
0          ENGINE
0          TYRES
0          RAILS
0          WINDOWS
0          CHAIN
0          STEERING

```

Now try entering this sequence which describes a CAR:

```

WHEELS Y   WINGS N   ENGINE Y   TYRES Y
RAILS N    WINDOWS Y  CHAIN N    STEERING Y

```

DE% is still 0, so the wrong conclusion is reached and the wrong question is asked (BICYCLE) to which the answer must be 'no':

DE% = 0

IS IT A BICYCLE? N

Now as a mistake was made the decision rule is modified by subtracting 1 from each value in the rule array where a 'yes' answer was given. The contents of the rule array are thus now:

## RULES

```

-1      WHEELS
0       WINGS
-1      ENGINE
-1      TYRES
0       RAILS
-1      WINDOWS
0       CHAIN
-1      STEERING

```

If you now enter the values which describe a CAR once more, the program will come up with the correct answer:

```

WHEELS Y   WINGS N   ENGINE Y   TYRES Y
RAILS N    WINDOWS Y  CHAIN N    STEERING Y

```

DE% = -5

IS IT A CAR? Y

## RULES

```

-1      WHEELS
0       WINGS
-1      ENGINE
-1      TYRES
0       RAILS
-1      WINDOWS
0       CHAIN
-1      STEERING

```

Before you feel too pleased with yourself, try giving it the values for a BICYCLE again, which it will get wrong!

```

WHEELS Y   WINGS N   ENGINE N   TYRES Y
RAILS N    WINDOWS N  CHAIN Y    STEERING Y

```

DE% = -3

IS IT A CAR? N

## RULES

```

0       WHEELS
0       WINGS
-1      ENGINE
0       TYRES
0       RAILS
-1      WINDOWS
1       CHAIN
0       STEERING

```

However the positive features which are common to the BICYCLE and the CAR are now automatically increased by 1, so that if you repeat this last sequence it will now produce the correct conclusion:

```

WHEELS Y   WINGS N   ENGINE N   TYRES Y
RAILS N    WINDOWS N  CHAIN Y    STEERING Y

```

DE% = 1  
IS IT A BICYCLE? Y

## RULES

```

0       WHEELS
0       WINGS
-1      ENGINE
0       TYRES
0       RAILS
-1      WINDOWS
1       CHAIN
0       STEERING

```

The situation has now stabilised and the program will always recognise both CAR and BICYCLE correctly every time you enter the features which describe them:

```

WHEELS Y   WINGS N   ENGINE Y   TYRES Y
RAILS N    WINDOWS Y  CHAIN N    STEERING Y

```

DE% = -2

IS IT A CAR? Y

## RULES

```

0       WHEELS
0       WINGS

```

```

-1      ENGINE
0       TYRES
0       RAILS
-1      WINDOWS
1       CHAIN
0       STEERING

```

Notice that the final value of DE% for a BICYCLE is 1, and for a CAR -2. If you look at the rule array values, you will see that these correspond in both number and position to the unique features which distinguish these objects (CHAIN for BICYCLE, and ENGINE and WINDOWS for CAR).

### A wider spectrum

Although you have now managed to teach your computer something, it is not exactly earth-shattering to be able to distinguish between only two objects. Let's expand the system to deal with a wider spectrum of possibilities (see Flowchart 6.2).

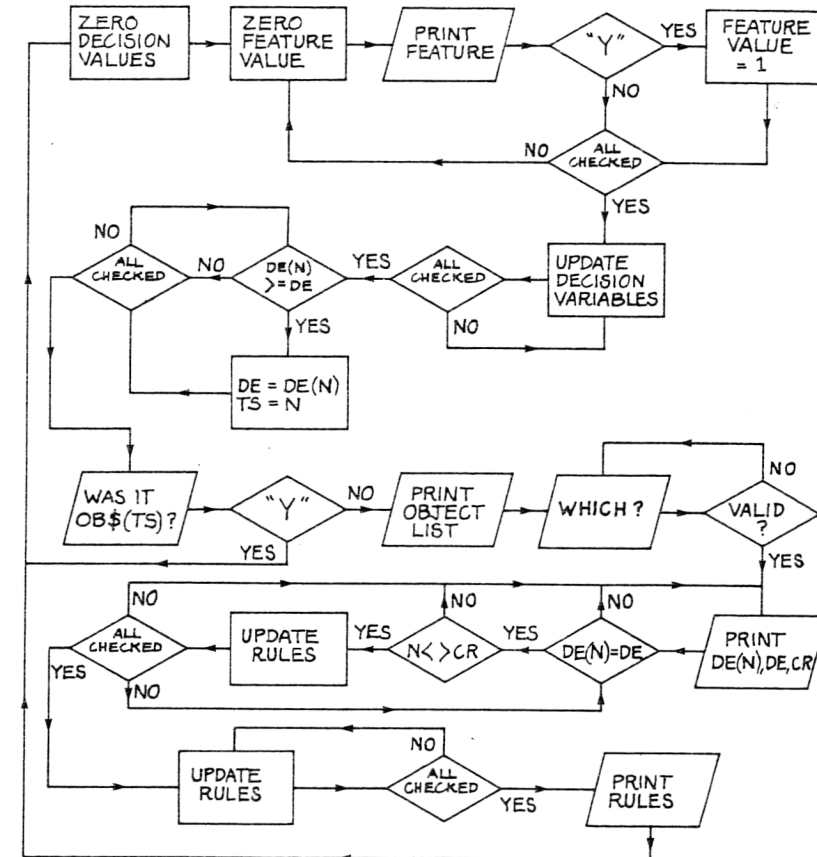
To start with we need to define the number of objects (outcomes) we wish to be able to recognise, OB%, name them as DATA which we READ into a new array, OB\$(OB%), change our decision rule array into a two-dimensional form, RU(FE%, OB%), which can hold rules for each of the objects separately, and set up a decision array, DE(N), to hold decision values for each object.

#### 20 START

```

11000 DEFine PROCedure START
11010  RESTORE
11020  FE%=8 : OB%=5 : DIM FE$(FE%,8),FV(FE%),
      RU(FE%,OB%),OB$(OB%,7),DE(OB%) : TS%=3
11030  FOR N=1 TO FE%
11040    READ FE$(N)
11050  END FOR N
11060  DATA "WHEELS","WINGS","ENGINE","TYRES",
      "RAILS","WINDOWS","CHAIN","STEERING"
11070  FOR N=1 TO OB%
11080    READ OB$(N)
11090  END FOR N
11100  DATA "BICYCLE","CAR","PLANE","TRAIN",
      "HORSE"
11110 END DEFine START

```



Flowchart 6.2: Learning the Rules for a Wider Spectrum of Possibilities.

Rather than just having a single decision variable, DE%, we need here to determine a decision value for each object each time. In each cycle we must first set DE% to zero, and then zero every element in the decision array, DE(N), so that we start with a clean state for every object (ZERO\_DE).

#### 50 ZERO\_DE

```

14000 DEFine PROCedure ZERO_DE
14010  DE%=0
14020  FOR N=1 TO OB%

```

```

14030      DE(N)=0
14040      END FOR N
14050 END Define ZERO_DE

```

Questions on the values for each feature are then entered in the same way as before.

```

40  REPEAT QUESTION

60      FOR N=1 TO FE%
70      FV(N)=0
80      PRINT !FE$(N);
90      IN$=INKEY$(-1)
100     IN$=CHR$((CODE(IN$) !! 32)-32)
110     PRINT !IN$;
120     IF IN$="Y" THEN FV(N)=1
130     END FOR N

200  END REPEAT QUESTION

```

UPDATE\_DV now updates each element of the decision array, DE(N), according to the status of the entered values, FV(N), and the contents of the appropriate rule array element, RU(N,M).

```

140      UPDATE_DV

15000 Define PROCEDURE UPDATE_DV
15010  FOR N=1 TO FE%
15020  FOR M=1 TO OB%
15030  DE(M)=((DE(M)*3)+((FV(N)*
      RU(N,M))*3))/3
15040  END FOR M
15050  END FOR N
15060 END Define UPDATE_DV

```

We now need to look to see if any of the DECISION values for any of the objects, DE(N), are greater than or equal to the overall decision value, DE%. If this is true then we set a 'top score', TS%, variable equal to the number of the object producing the best match, N.

```

150      DECISION

```

```

16000 Define PROCEDURE DECISION
16010  FOR N=1 TO OB%
16020  IF DE(N)>=DE% THEN DE%=DE(N) : TS%=N
16030  END FOR N
16040 END Define DECISION

```

The best guess of the system is that this is the correct answer, so once again it asks for confirmation, and simply returns for a new input without making any changes if the answer was correct.

```

160      ANSWER

```

```

17000 Define PROCEDURE ANSWER
17010  PRINT "\"WAS IT ";OB$(TS%);" ";
17020  IN$=INKEY$(-1)
17030  IN$=CHR$((CODE(IN$) !! 32)-32)
17040  PRINT IN$
17050  IF IN$="Y" THEN NEXT QUESTION
17060 END Define ANSWER

```

However, if the answer needs correction, the names and numbers of all of the objects are printed out and you are asked for the number of the correct answer, CR%. (The limitations on CR% prevent you crashing the program by entering an illegal value.)

```

170      CORRECTION

```

```

18000 Define PROCEDURE CORRECTION
18010  FOR N=1 TO OB%
18020  PRINT \N,OB$(N);
18030  END FOR N
18040  PRINT "\"WHICH WAS IT? ";
18050  IN$=INKEY$(-1)
18060  CR%=CODE(IN$)-48 : IF CR%<1 OR CR%>5
      THEN CORRECTION
18070  PRINT CR%
18080 END Define CORRECTION

```

To UPDATE\_RULES we must first make a check to determine whether the decision value for each object, DE(N), is greater than or equal to the

overall decision value, DE%, AND whether the object being considered is NOT the correct answer. If *both* of these are true then the rules are updated again by subtracting the correct feature values, FV(N), to bias in favour of the correct answer.

```

180      UPDATE_RULES

19000  DEFine PROCedure UPDATE_RULES
19010      FOR N=1 TO OB%
19020      IF DE(N)>=DE% AND N<>CR% THEN
19030          FOR M=1 TO FE%
19040              RU(M,N)=(RU(M,N)*3)-
                  (FV(M)*3))/3
19050          END FOR M
19060      ELSE NEXT N
19070      END IF
19080      END FOR N

```

Then the correct feature values, FV(N), are added to the rule array for the correct object to bias in the opposite direction.

```

19090      FOR M=1 TO FE%
19100          RU(M,CR%)=(RU(M,CR%)*3)+
                  (FV(M)*3))/3
19110      NEXT M
19120  END DEFine UPDATE_RULES

```

Finally DISPLAY\_RULES prints out the status of the rule arrays so that you can see what is happening.

```

190      DISPLAY_RULES

20000  DEFine PROCedure DISPLAY_RULES
20010      CLS #2 : CLS #3
20020      FOR M=1 TO OB%
20030          AT #2,3,M-1 : PRINT #2,DE(M);"
                  ";DE%;"          ";CR%"
20040          FOR N=1 TO FE%
20050              AT #3,(N*3)-3,M-1 : PRINT
                  #3,RU(N,M);
20060          END FOR N

```

```

20070      END FOR M
20080      PRINT
20090  END DEFine DISPLAY_RULES

```

To make the whole program easier to understand we will use the capabilities of the QL to produce a comprehensive screen status format (see **Figure 6.1**) with multiple windows. These are produced by the SCREEN\_SET PROCedure and then LABELled appropriately. Although we will omit any discussion on the details of this 'decorative' aspect of the program, we should explain that the main action takes place in the default window (right half of screen), with printouts of DE(N), DE% and CE% in window #2, the rules in window #3, and various labels in windows #4, #5 and #6.

Note that a separate SCREEN PROCedure is defined which not only clears the whole screen to start with but also provides you with a safety net which can easily return you to an acceptable format for listing the program. The two parameters passed to SCREEN are PAPER and INK, respectively, hence typing SCREEN 6,0 as a direct command before LIST will automatically return the full screen area and produce a black listing on a white background.

```

10  SCREEN 0,6 : SCREEN_SET
30  LABEL

10000  DEFine PROCedure SCREEN_SET
10010      MODE 0
10020      CLS #0
10030      INK #0,7
10100      WINDOW #1,230,200,257,16
10110      BORDER #1,3,6
10120      CSIZE #1,2,0
10130      PAPER #1,5
10140      INK #1,0
10150      CLS #1
10200      WINDOW #2,140,50,105,32
10220      CSIZE #2,0,0
10240      INK #2,2
10250      CLS #2
10300      OPEN #3,SCR_170X60AB5X100
10310      BORDER #3,3,2
10320      CSIZE #3,0,0
10330      PAPER #3,6
10340      INK #3,0

```

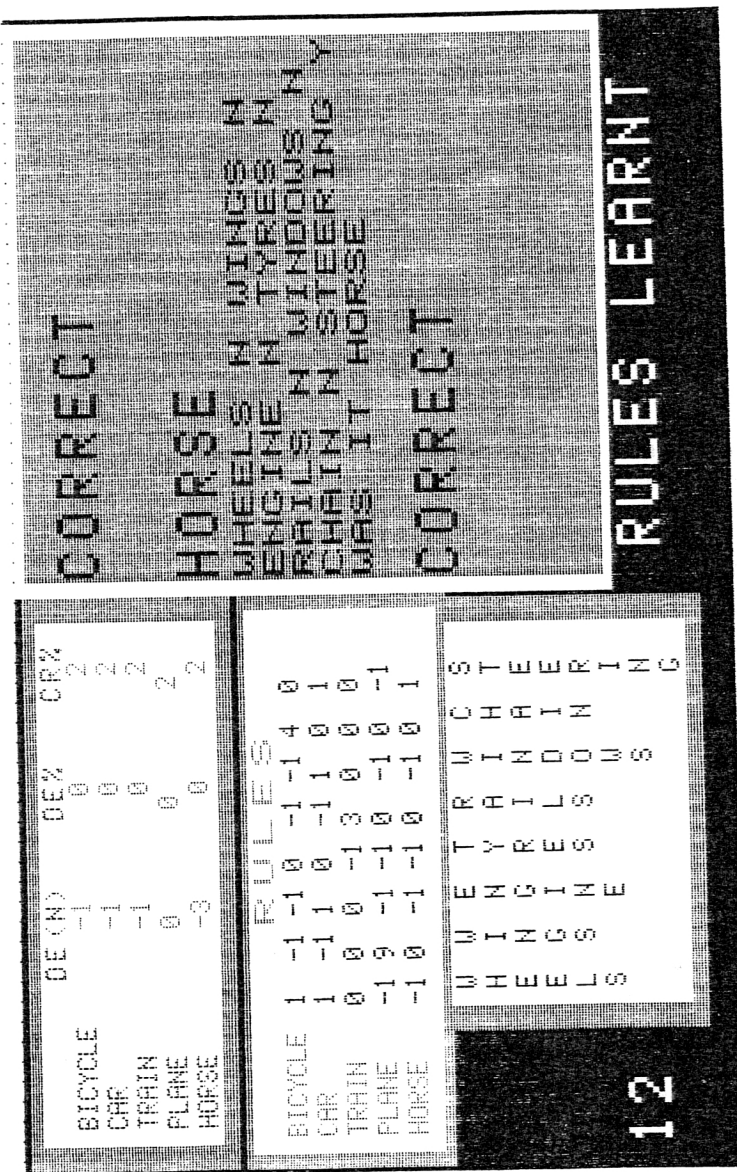


Figure 6.1: A Learning Expert.

```

10350   CLS #3
10400   OPEN#4,SCR_175X90A80X155
10410   BORDER #4,5,2
10420   CSIZE #4,0,0
10430   INK #4,1,0
10440   PAPER #4,6
10450   CLS #4
10500   OPEN#5,SCR_230X70A26X90
10510   BORDER #5,3,2
10520   CSIZE #5,0,0
10530   INK #5,4
10540   PAPER #5,6
10550   CLS #5
10600   OPEN #6,SCR_230X70A26X18
10610   BORDER #6,5,2
10620   CSIZE #6,0,0
10630   INK #6,1,4
10640   PAPER #6,6
10650   CLS #6
10700   END DEFine SCREEN_SET

20000   DEFine PROCedure SCREEN (A,B)
20010   WINDOW #2,460,200,26,16
20020   PAPER #2,A
20030   INK #2,B
20040   CLS #2
20050   END DEFine SCREEN

13000   DEFine PROCedure LABEL
13010   AT #6,11,0 : CSIZE #6,1,0 : PRINT
        #6,"DE(N)  DE%  CR%" : CSIZE #6,0,0
13020   FOR N=1 TO OB%
13030   AT #6,1,N : PRINT #6,OB*(N)
13040   AT #5,1,N : PRINT #5,OB*(N)
13050   END FOR N
13060   FOR N=1 TO FE%
13070   FOR M=1 TO 8
13080   AT #4,(N*3)-2,M-1
13090   PRINT #4,FE*(N,M)
13100   AT #5,15,0 : CSIZE #5,3,0 : PRINT
        #5,"RULES" : CSIZE #5,0,0
13110   END FOR M
13120   END FOR N
13130   END DEFine LABEL

```



Once again a demonstration is the best way to understand what is happening so enter the following sequence:

```
WHEELS Y    WINGS N
ENGINE N    TYRES Y
RAILS N     WINDOWS N
CHAIN Y     STEERING Y
```

The program will come back with the erroneous conclusion that it was a HORSE, so you must tell it that this was wrong, when it will ask you for the correct answer (BICYCLE = 1):

WAS IT HORSE N

```
1      BICYCLE
2      CAR
3      TRAIN
4      PLANE
5      HORSE
```

WHICH WAS IT 1

The status of the various decision and rule arrays are now printed out for your information, in the windows on the lefthand side of the screen.

	DE (N)	DE%	CR%
BICYCLE	0	0	1
CAR	0	0	1
TRAIN	0	0	1
PLANE	0	0	1
HORSE	0	0	1

#### RULES

BICYCLE	1	0	0	1	0	0	1	1
CAR	-1	0	0	-1	0	0	-1	-1
TRAIN	-1	0	0	-1	0	0	-1	-1
PLANE	-1	0	0	-1	0	0	-1	-1
HORSE	-1	0	0	-1	0	0	-1	-1

```
W  W  E  T  R  W  C  S
H  I  N  Y  A  I  H  T
E  N  G  R  I  N  A  E
E  G  I  E  L  D  I  E
L  S  N  S  S  O  N  R
S              W  I
                S  N
                S  G
```

If you look closely you will see that the features which have caused alterations in the rule arrays are wheels, tyres, chain and steering — which are all features which we defined as part of a BICYCLE but which are not found in a HORSE. In addition you will see that the values for these features in the BICYCLE rule array are now all +1, whilst the values for these features for all the other objects are all now -1. Now give it the features of a CAR, which it thinks is a BICYCLE, and then correct it. Notice that the rule arrays for BICYCLE and CAR are now amended to take into account the new information.

```
WHEELS Y    WINGS N
ENGINE Y    TYRES Y
RAILS N     WINDOWS Y
CHAIN N     STEERING Y
```

WAS IT BICYCLE N

```
1      BICYCLE
2      CAR
3      TRAIN
4      PLANE
5      HORSE
```

WHICH WAS IT 2

	DE (N)	DE%	CR%
BICYCLE	3	3	2
CAR	-3	3	2
TRAIN	-3	3	2
PLANE	-3	3	2
HORSE	-3	3	2

#### RULES

BICYCLE	0	0	-1	0	0	-1	1	0
CAR	0	0	1	0	0	1	-1	0
TRAIN	-1	0	0	-1	0	0	-1	-1
PLANE	-1	0	0	-1	0	0	-1	-1
HORSE	-1	0	0	-1	0	0	-1	-1

W	W	E	T	R	W	C	S
H	I	N	Y	A	I	H	T
E	N	G	R	I	N	A	E
E	G	I	E	L	D	I	E
L	S	N	S	S	O	N	R
S		E			W		I
					S		N
							G

Next give it a PLANE, which it decides is a CAR, and correct it again.

WHEELS Y	WINGS Y
ENGINE Y	TYRES Y
RAILS N	WINDOWS Y
CHAIN N	STEERING Y

WAS IT CAR N

1	BICYCLE
2	CAR
3	TRAIN
4	PLANE
5	HORSE

WHICH WAS IT 4

And now a TRAIN, which it still gets wrong!

WHEELS Y	WINGS N
ENGINE Y	TYRES N
RAILS N	WINDOWS Y
CHAIN N	STEERING N

WAS IT PLANE N

1	BICYCLE
2	CAR
3	TRAIN

4	PLANE
5	HORSE

WHICH WAS IT 3

And finally a HORSE, which comes out as a PLANE!

WHEELS N	WINGS N
ENGINE N	TYRES N
RAILS N	WINDOWS N
CHAIN N	STEERING Y

WAS IT PLANE N

1	BICYCLE
2	CAR
3	TRAIN
4	PLANE
5	HORSE

WHICH WAS IT 5

If you continue to feed your expert information then eventually it will get the right answer every time. How long this will take depends upon the extent of the differences between the features of the objects, and on the order in which the objects are presented to the expert. Be warned that it can take a long time before it becomes infallible! Here is one sequence which eventually was right every time.

PLANE (TRAIN)	CAR (PLANE)	BICYCLE (YES)
CAR (YES)	PLANE (CAR)	PLANE (YES)
HORSE (YES)	PLANE (BICYCLE)	CAR (PLANE)
PLANE (CAR)	PLANE (CAR)	CAR (PLANE)
CAR (YES)	PLANE (CAR)	PLANE (YES)
CAR (YES)	PLANE (YES)	HORSE (YES)
BICYCLE (YES)	TRAIN (CAR)	TRAIN (YES)
BICYCLE (YES)	CAR (PLANE)	CAR (YES)
PLANE (CAR)	PLANE (YES)	CAR (PLANE)
CAR (YES)	PLANE (YES)	CAR (YES)
BICYCLE (CAR)	CAR (YES)	PLANE (YES)
TRAIN (YES)	HORSE (YES)	BICYCLE (YES)

As the final scale of values ranged from +6 to -2 you should not be surprised that it took a long time to get there.

## RULES

BICYCLE	1	0	-1	1	0	-2	3	0
CAR	-1	4	1	0	-1	1	-2	0
TRAIN	0	-1	1	-2	2	1	-1	-2
PLANE	-2	6	0	0	-1	0	-2	-2
HORSE	-1	0	0	-1	0	0	-1	0

W	W	E	T	R	W	C	S
H	I	N	Y	A	I	H	T
E	N	G	R	I	N	A	E
E	G	I	E	L	D	I	E
L	S	N	S	S	O	N	R
S		E			W		I
					S		N
							G

**Automatic digestion of the data**

Although our expert now manages to sort out the rules for itself, we are still left with the tedious job of holding a 'conversation' with it, whilst it builds up the correct pattern in its rule arrays. In a real application of such an expert system it would be much better if we could feed it a mass of collected information on a subject area and the conclusions, and then leave it alone to digest this and come up with the rules automatically in its own good time.

In fact it is not too difficult to modify our existing program to produce an 'automatic' mode which crunches information provided as DATA.

First of all we need to enter that information in a fixed format containing the name of the particular object and 'Y' and 'N' answers for each feature, in the correct order.

```

25000 REMark INFORMATION STORE
25010 DATA "BICYCLE", "Y", "N", "N", "Y",
      "N", "N", "Y", "Y"
25020 DATA "CAR", "Y", "N", "Y", "Y",
      "N", "Y", "N", "Y"
25030 DATA "TRAIN", "Y", "N", "Y", "N",
      "Y", "Y", "N", "N"
25040 DATA "PLANE", "Y", "Y", "Y", "Y",
      "N", "Y", "N", "Y"
25050 DATA "HORSE", "N", "N", "N", "N",
      "N", "N", "N", "Y"
25060 DATA "END"

```

We now introduce a READER PROCedure, called at the start of the QUESTION loop, which, for the moment, just READs and PRINTs out the name (N\$) of the object currently being examined.

**45 READER**

```

26000 DEFine PROCedure READER
26030 READ N$
26100 CSIZE 3,1 : PRINT N$ : CSIZE 2,0
26110 END DEFine READER

```

The 'Y' and 'N' answers for each feature are also READ in turn, as IN\$, in a replacement for the previous INKEY\$ check in the QUESTION loop.

**90 READ IN\$**

In the ANSWER PROCedure, we need to compare the name of the object being examined (N\$) with the name of the top-scoring object (OB\$(TS%)) selected by our expert. If a match is found then 'CORRECT' is printed.

```

14020 IF OB$(TS%)=N$ THEN
14030 CSIZE 3,1 : PRINT "\"CORRECT\"\\ :
      CSIZE 2,0
14040 NEXT QUESTION
14050 END IF

```

In the CORRECTION PROCedure we need to compare the name of the item currently being examined (N\$) with the names of each of the objects (OB\$(N)) which are known by our expert. The best way to do this is to insert a check inside the listing loop which sets CR% to N when there is a match. The original INKEY\$ and following validation check must also be removed.

```

17025 IF OB$(N)=N$ THEN CR%=N
17050 REMark DELETED
17060 REMark DELETED

```

Once those changes have been made you can sit back, or perhaps indulge in a cup of coffee, as you watch your expert hard at work!

## Round and round

As it stands the program will end when all of the objects have been examined once which, as you should have already noticed, is not enough to build the correct rules. We can force repeat cycling by checking whether the 'END' message following the real DATA has been detected, and RESTOREing to the appropriate line number. Notice that we must READ N\$ again after the RESTORE.

```
26040      IF N$="END" THEN
26050          RESTORE 27000
26080          READ N$
26090      END IF
```

To be able to see how well our expert is doing and to be able to congratulate him when he has finished his task, we need to keep track of how many cycles of testing have been completed, and whether full success has been achieved. Two new variables are defined. CY% is the number of cycles of comparisons completed, and SU% is the success achieved. SU% must be incremented in the ANSWER PROCedure, reset on RESTORE, and be compared with the number of objects to be correctly identified (5). A printout of the current cycle is produced in the bottom left hand corner of the screen on channel #0, so that you can assess progress, and a 'RULES LEARNT' message appears when SU% reaches 5.

```
5 CY%=1 : SU%=0
```

```
14040      SU%=SU%+1 : NEXT QUESTION
```

```
26010      IF SU%=5 THEN STOP
26020      AT #0,0,0 : CSIZE #0,3,1 : PRINT #0,
          CY% : CSIZE #0,0,0
```

```
26070      SU%=0
```

When you test out this automated version you will discover *six* cycles of the DATA are required to guarantee successful recognition of the five modes of transport as the DATA is entered. However, if you switch the positions of the BICYCLE and the HORSE this reduces to only *four* cycles. With PLANE swapped with BICYCLE only four cycles are again needed, but with BICYCLE and CAR switched the requirement rises to no less than *twelve* cycles! It is also interesting to note that the final rules differ in each case. We leave you to experiment with random selection of the DATA, as well as expansion of the field of knowledge.

## Keeping your expert

Now that your expert has been trained it would be a pity to lose him when the power goes off. However, as the rules are stored in arrays, you could easily write a routine to save them and then reload them for use at a later date.

## CHAPTER 7

### Fuzzy Matching

Computers are totally logical but our own memory banks are much more unreliable, which can lead to problems when you are trying to recover information on a particular subject. For example English is a very variable language and there are frequently alternative spellings of the same (or very similar) surnames, which can cause difficulties. One way round this problem is to try to match the sound of the word rather than the actual letters in it by means of 'soundex coding', which was originally developed to assist processing of the 1890 census in the USA. This method of coding ensures that similar sounding words have almost the same code sequence. The rules for coding a word are as follows:

- 1) Always retain the first letter of the word as the first character of the code. From the second letter onward:
- 2) Ignore vowels (a, e, i, o, u).
- 3) Ignore the letters w, y, q and h.
- 4) Ignore punctuation marks.
- 5) Code the other letters with the values 1–6 as follows:

Letters	Code
bfpv	1
cgjksxz	2
dt	3
l	4
mn	5
r	6

- 6) Where adjacent letters have the same code only the first one is retained.
- 7) If length of code is greater than four characters then take first four only.
- 8) If length of code is less than four characters then pad out to four characters with zeros.

To make this clear here are some examples of soundex coded names:

**BRAIN – B650:** B is retained, R is 6, A and I are dropped, N is 5 and a zero is added to pad out the code.

**CUNNINGHAM – C552:** C is retained, U is dropped, both Ns are represented by the single code 5, I is dropped, the third N is represented by 5, G is 2, H and A are dropped, and M is coded as 5 — but the resulting code (C5525) is truncated to four characters.

**GORE – G600:** G is retained, O is dropped, R is 6, E is dropped and zeros are added to pad the code.

**IRELAND – I645:** I is retained, R is 6, E is dropped, L is 4, A is dropped, N is 5 and D is 3 — but the resulting code (I6453) is truncated to four characters.

**SCOT – S300:** S is retained, C is dropped because it is in the same group as S, O is dropped, T is 3 and zero is added to pad the code.

If your name is full of vowels and other rejected letters then you will find that your code is somewhat abbreviated!

**HEYHOE – H000:** H is retained, all the other letters are rejected (!), and the code is filled up with zeros.

### Coding routine

To save all that brainwork let's develop a program which allows you to input a word in English and output it in soundex code (see **Flowchart 7.1**). The first thing to do is to jump to a **SET\_UP** routine which first of all **RESTOREs** the **DATA** pointer and then calls **SCREEN** which sets up a suitable series of screen windows.

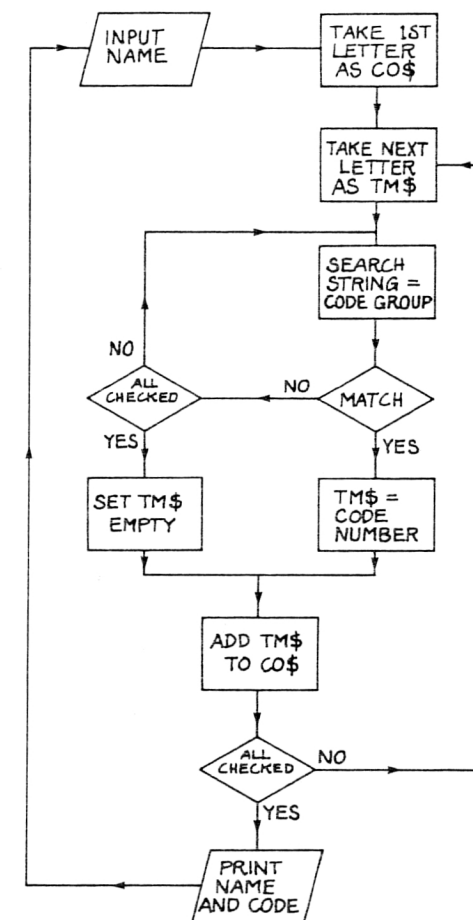
#### 10 SET\_UP

```
10000 DEFine PROCedure SET_UP
10010  RESTORE
10020  SCREEN
10030  CODES
```

```
10050 END DEFine SET_UP
```

The **SCREEN** display is divided vertically into two main windows (#1 and #2), with #0 at the bottom reserved for **INPUT**, and #3 and #4 at the top of the screen used for labels (see **Figure 7.1**).

```
11000 DEFine PROCedure SCREEN
11010  MODE 4
```



Flowchart 7.1: Producing a Soundex Code.

```
11020 WINDOW #2,230,186,26,30
11030 BORDER #2,2,6
11040 CSIZE #2,1,0
11050 CLS #2
11060 WINDOW #1,230,186,257,30
11070 BORDER #1,2,4
11080 CSIZE #1,1,0
11090 PAPER #1,5
11100 INK #1,0
11110 CLS#1
```



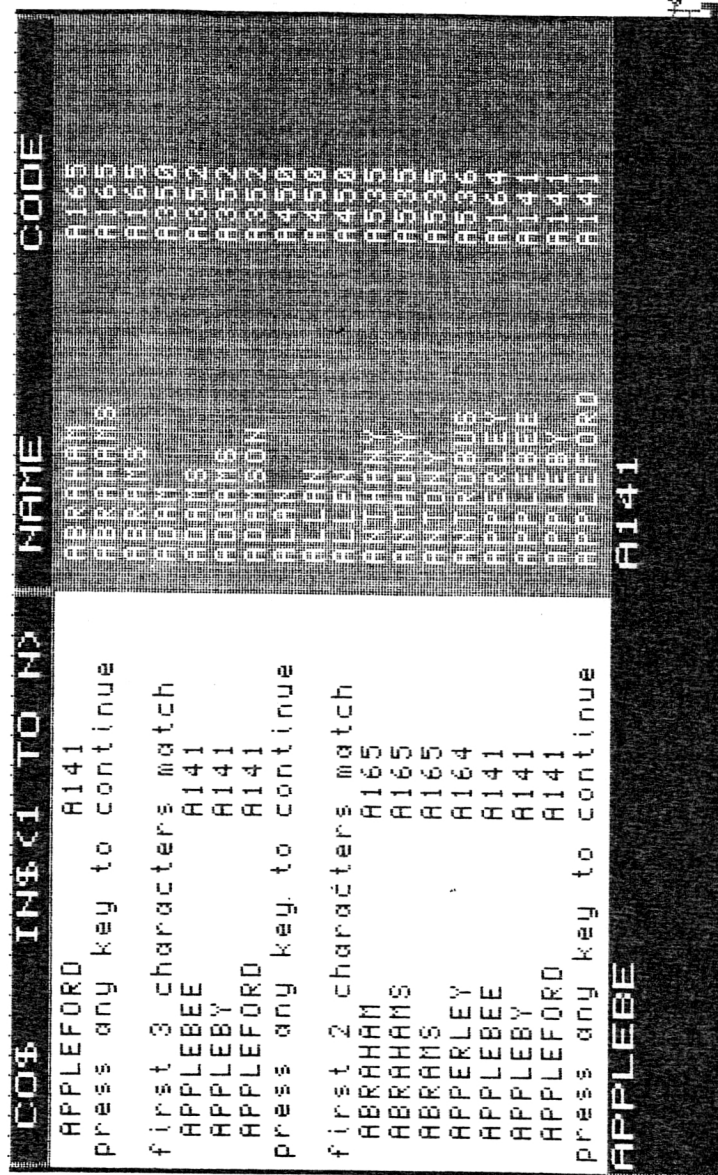


Figure 7.1: Fuzzy Matching.

```

11120 BORDER #0,1,4
11130 CSIZE#0,2,0
11140 CLS #0
11150 OPEN #3,SCR_230X14A257X16
11160 OPEN #4,SCR_230X14A26X16
11170 BORDER #3,1,4
11180 BORDER #4,1,4
11190 CSIZE #3,2,0
11200 CSIZE #4,2,0
11210 PAPER #3,0
11220 PAPER #4,0
11230 INK #3,7
11240 INK #4,7
11250 CLS#3
11260 CLS#4
11270 PRINT #3," NAME"," CODE"
11280 PRINT #4," CO#"," ";IN$(1 TO N);
11290 END Define SCREEN

```

The CODES PROCedure reads each group of the retained letters into one element of a soundex code string array, SC\$(n). Note that these groups are arranged so that the letters are in the array element corresponding to their code value.

```

12000 Define PROCedure CODES
12010 DIM SC$(6,7)
12020 DATA "BFPV","CGJKSXZ","DT","L","MN","R"
12030 FOR N=1 TO 6
12040 READ SC$(N)
12050 END FOR N
12060 END Define CODES

```

We can now INPUT the word to be converted, IN\$. (A mug-trap is provided for an empty string, but if you want to convert automatically from lower case you can include the GET\$ PROCedure described in Chapter 2.)

```

100 REPEAT LOOP
110 AT #0,1,2 : INPUT #0,IN$; : IF
    IN$="" THEN LOOP
140 END REPEAT LOOP

```

As conversion to the code numbers and compilation of a soundex code string will be required at various points, we will set this process up as a FuNction named COMPILE\$. As this is a FuNction we can easily PRINT out the result of passing IN\$ to it.

```
120 AT #0,20,2 : PRINT #0, COMPILE$
    (IN$)\
```

To begin with we must make the coded version of this, COS\$, the first letter of the INPUT word (following the first rule above).

```
15000 DEFine FuNction COMPILE$ (IN$)
15010 TM$=IN$(1) : CO$=TM$ : CONVERSION
```

For conversion of each letter to the appropriate code character, we have to check TM\$ against each individual letter in each group of letters, SC\$(N), to find a match. To check each letter group we have to go round six times, making a search string, SE\$, the current soundex code group and using an INSTR routine which checks each letter in the group against TM\$ in turn.

```
16000 DEFine PROCedure CONVERSION
16010 LOCAL P
16020 FOR P=1 TO 6
16030 SE$=SC$(P)
16040 SP%=TM$ INSTR SE$
```

When the INSTR check has been made we have to determine whether a match has been found to any of the soundex groups, and, if so, to which group. If no match is found then SP% will be set to 0. On the other hand if a match is found then SP% will be set to P which will point to the value of the code group matched. If a match was found (SP%>0) then we convert the value of the loop scanning the code groups, P, to a string, TM\$, which replaces our original temporary string.

```
16050 IF SP%>0 THEN TM$=P : RETURN
```

If no match is found in that group, we have to check the next group.

```
16060 END FOR P
```

If no match is found at all then TM\$ must contain one of the characters to be ignored so we reset TM\$ empty — TM\$="".

```
16070 TM$=""
16080 END DEFine CONVERSION
```

We then need to check the other letters of the word, 2 TO LEN(IN\$), in turn after first making a temporary string, TM\$, equal to the current letter to be translated.

```
15030 FOR N=2 TO LEN(IN$)
15040 TM$=IN$(N)
15050 CONVERSION
```

We can now make the coded string, COS\$, equal to the original coded string plus the newly-converted character, TM\$, and RETURN the final result when all characters in IN\$ have been checked.

```
15080 CO$=CO$&TM$
15110 END FOR N
15140 PRINT #2
15150 RETURN CO$
15160 END DEFine COMPILE$
```

The final converted code will eventually be printed out at the bottom of the screen (next to the INPUT) but it would be instructive to watch how the computer reaches its decision. Adding the following line to the COMPILE\$ routine will provide a detailed printout of the state of play during each cycle of the conversion in the lefthand window.

```
15100 PRINT #2, " "; CO$, , IN$(1 TO N)
```

If you INPUT the name STEVEN you will get the code S315, by the following route:

```
COS$      IN$(1 TO N)
S3         ST
S3         STE
S31        STEV
S31        STEVE
S315       STEVEN
```

However, if you try BRAIN or CUNNINGHAM you will get codes B65 and C55525 respectively.

CO\$	IN\$(1 TO N)
B6	BR
B6	BRA
B6	BRAI
B65	BRAIN
C	CU
C5	CUN
C55	CUNN
C55	CUNNI
C555	CUNNIN
C5552	CUNNING
C5552	CUNNINGH
C5552	CUNNINGHA
C55525	CUNNINGHAM

The code for BRAIN is too short, and needs padding out with zeros, and the code for CUNNINGHAM is too long and the same codes are repeated one after another for the letter N.

### Dealing with the details

To solve the problem of the repetition of the same code for adjacent letters, we need to keep a record of the last temporary string, LT\$. We need to make LT\$ the code of the first character in IN\$ to start with, so that the initial letter is not repeated. As we go through the FOR-NEXT loop we must then compare LT\$ with TM\$, and if they are the same we must not add TM\$ to CO\$. Otherwise we need to make LT\$ the latest TM\$.

```

15020  LT$=TM$
15060  IF TM$<>LT$ THEN
15070    LT$=TM$
15090  END IF

```

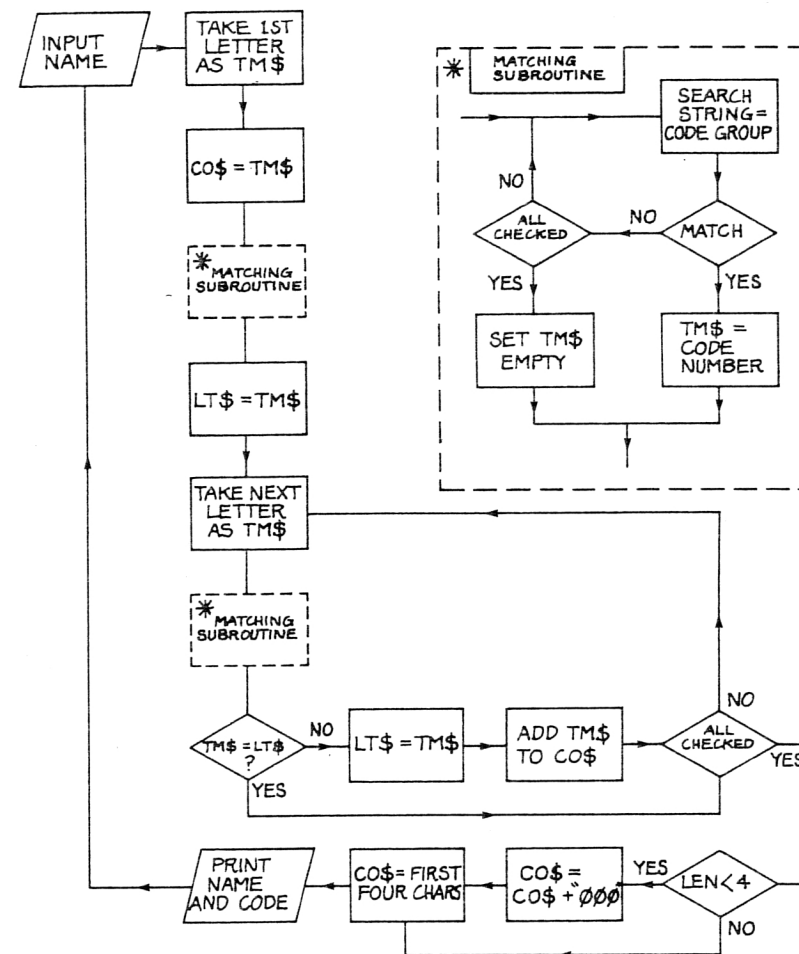
Now we can sort out the problem of the code being too short. First of all we check the length of the string, LEN(CO\$)<4. If it is too short we add three zeros on to the end and then cut the string back down to the correct size (four characters).

```

15120  IF LEN(CO$)<4 THEN CO$=CO$&"000"
        CO$=CO$(1 TO 4)

```

Finally if the string is too long then we cut it down to size with CO\$(1 TO 4) again (see Flowchart 7.2).



Flowchart 7.2: Dealing with the Details.

```

15130  IF LEN(CO$)>4 THEN CO$=CO$(1 TO
        4)

```

### Matchmaking

Now that we have a reliable method of producing the soundex codes, let's give it something to work on. The first task is to READ a list of names out

of DATA statements into a name string array, NA\$(N). Our demonstration list only consists of 18 names, but if you want more a quick flick through your local telephone directory should soon solve that problem! Note that the number of words is also stored as NW%, and that this PROCEDURE is now called from within SET\_UP.

```
10040 NAMES

13000 DEFINE PROCEDURE NAMES
13010 LT$="" : NW%=17
13020 DIM NA$(NW%,16) : DIM NC$(NW%,16)
13030 DATA "ABRAHAM","ABRAHAMS","ABRAMS",
          "ADAMS","ADDAMS","ADAMSON","ALAN",
          "ALLAN","ALLEN"
13040 DATA "ANTHANY","ANTHONY","ANTONY",
          "ANTROBUS","APPERLEY","APPLEBEE",
          "APPLEBY","APPLEFORD"
13050 FOR N=0 TO NW%
13060 READ NA$(N)
13070 END FOR N

13120 END DEFINE NAMES
```

The whole idea of matching with soundex codes relies on the fact you use the soundex code to make the match before printing the possible words. We therefore have to find the codes for each of the names from the DATA and put these codes into an equivalent string array, NC\$(N). However, this is easy as the previously DEFINED FUNCTION COMPILE\$ can be re-used to find the soundex code, if NA\$(Q) is passed instead of INS.

```
13080 FOR Q=0 TO NW%
13090 NC$(Q)=COMPILE$(NA$(Q))
13100 PRINT NA$(Q),NC$(Q)
13110 NEXT Q
```

If you RUN this now you will see all the codes for the DATA produced (on the left window) and displayed (on the right window) before the input request. However, the righthand display is rather ragged, so let's smarten it up by formatting it with a TABLE\$ FUNCTION. This puts the results into two neat columns by adding padding spaces to the righthand end of the strings, and then retaining only the first part of the result.

```
13100 PRINT TABLE$(NA$(Q),NC$(Q))

14000 DEFINE FUNCTION TABLE$(I1$,I2$)
14010 I1$=I1$ & FILL$(" ",16)
14020 I2$=I2$ & FILL$(" ",8)
14030 I1$=I1$(1 TO 16)
14040 I2$=I2$(1 TO 8)
14050 RETURN " "&I1$&I2$
14060 END DEFINE TABLE$
```

NAME	CODE
ABRAHAM	A165
ABRAHAMS	A165
ABRAMS	A165
ADAM	A350
ADAMS	A352
ADDAMS	A352
ADAMSON	A352
ALAN	A450
ALLAN	A450
ALLEN	A450
ANTHANY	A535
ANTHONY	A535
ANTONY	A535
ANTROBUS	A536
APPERLEY	A164
APPLEBEE	A141
APPLEBY	A141
APPLEFORD	A141

The only thing we need to do now is to compare the codes and determine which of these names match the code of your input.

```
130 COMPARE

17000 DEFINE PROCEDURE COMPARE

17030 FOR N=0 TO NW%
17040 IF CO$=NC$(N) THEN PRINT #2
          ,TABLE$(NA$(N),
          NC$(N))
17050 END FOR N

17090 END DEFINE COMPARE
```

This will only print words with exactly matching soundex codes. For example, if you try entering the name APPLEBE you will get the following response:

APPLEBE      A141

NAME	CODE
APPLEBEE	A141
APPLEBY	A141
APPLEFORD	A141

Although APPLEBE (one E at the end) is not present in the DATA, we have found APPLEBEE AND APPLEBY, as well as APPLEFORD (where the interesting sound at the end has been chopped off).

### Partial matching

Notice, however, that APPERLEY has been rejected, even though it sounds quite similar at first. It would therefore be useful if we could also print out partial matches.

This can easily be done by adding an extra FOR-NEXT loop which compares a decreasing section (1 TO M) of the INPUT with decreasing lengths of the stored codes (see Flowchart 7.3).

```
17010  FOR M=4 TO 1 STEP -1
17020    PRINT #2, "\"first ";M;" characters
        match\"
```

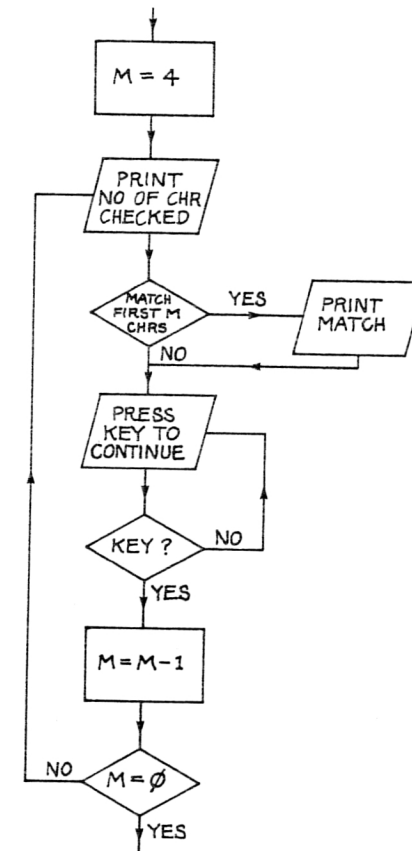
```
17040    IF CO$(1 TO M)=NC$(N) (1 TO M)
        THEN PRINT #2, TABLE$ (NA$(N),
        NC$(N))
```

```
17060    PRINT #2, "press any key to continue"
17070    DUMMY$=INKEY$(-1)
17080  END FOR M
```

If you now try APPLEBE, you can see the whole range of possibilities.

APPLEBE      A141

first 4 characters match  
 APPLEBEE      A141  
 APPLEBY        A141  
 APPLEFORD     A141  
 press any key to continue



Flowchart 7.3: Partial Matching.

first 3 characters match  
 APPLEBEE      A141  
 APPLEBY        A141  
 APPLEFORD     A141  
 press any key to continue

first 2 characters match  
 ABRAHAM        A165  
 ABRAHAMS       A165  
 ABRAMS          A165  
 APPERLEY       A164  
 APPLEBEE       A141

APPLEBY A141  
 APPLEFORD A141  
 press any key to continue

first 1 characters match  
 ABRAHAM A165  
 ABRAHAMS A165  
 ABRAMS A165  
 ADAM A350  
 ADAMS A352  
 ADDAMS A352  
 ADAMSON A352  
 ALAN A450  
 ALLAN A450  
 ALLEN A450  
 ANTHANY A535  
 ANTHONY A535  
 ANTONY A535  
 ANTROBUS A536  
 APPERLEY A164  
 APPLEBEE A141  
 APPLEBY A141  
 APPLEFORD A141  
 press any key to continue

## CHAPTER 8

### Recognising Shapes

We normally recognise objects using our senses of sight, sound, taste and feel, whereas of course our basic computer can only obtain information through the keyboard. Whilst it is possible to produce sensors which can be interfaced to your machine to give it another view of the outside world, constructing these requires a reasonable amount of electronic and mechanical knowledge and skill. We will make do instead with a simulation of the action of a light sensor to illustrate how shapes can be recognised.

Let us think for a start about three simple shapes — a vertical line, a square, and a right-angled triangle.

We can recognise these shapes by looking at the pattern they make on an imaginary grid and deciding whether or not there is a point set at each X and Y coordinate.

In the case of the line, only the first X coordinate is used, but all of the Y coordinates. The square is a little more complicated, as all the X coordinates on Y rows 1 and 8 are set, but from Y rows 2 to 7 only the first and last X points are set. Finally the triangle is even more complicated as the slope is produced by incrementing the X axis each time.

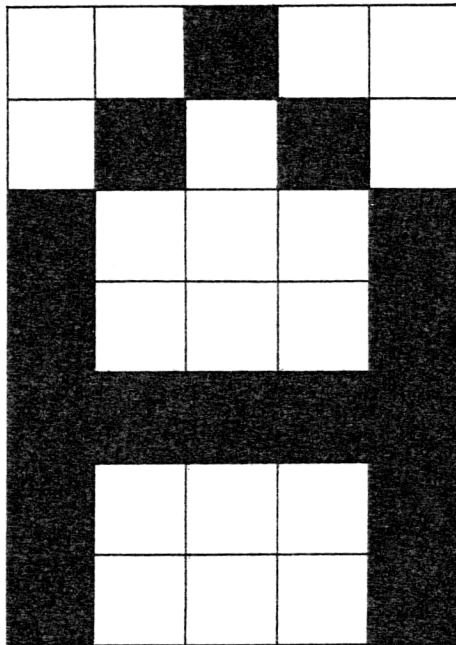
Table 8.1: Decimal Values of Shapes Described in Binary Form.

Y row	line	square	triangle
1	1	255	1
2	1	129	3
3	1	129	5
4	1	129	9
5	1	129	17
6	1	129	33
7	1	129	65
8	1	255	255

One obvious way to describe these particular figures would be to represent each point by a single bit and produce a decimal value for each row in the same way as we did before when we were looking at expert systems (see Table 8.1). In fact this type of approach is used to produce



the characters which you see on your screen display, the formats for which are stored in memory in just this form. For example, **Figure 8.1** shows how the letter 'A' is built up.



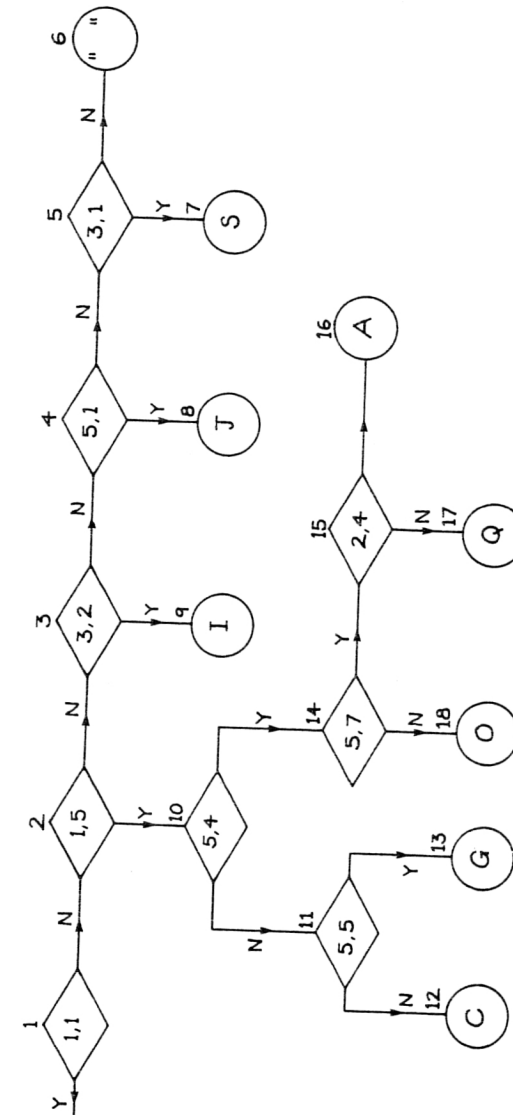
**Figure 8.1: Forming the Letter 'A'.**

There are now machines available (optical character readers) which can reverse this process and actually 'read' a printed page by scanning the paper in a grid pattern and measuring whether light is reflected at particular coordinates.

What they actually take in will be a pattern of 'yes' and 'no' for each coordinate and of course this must then be decoded and compared with the patterns for known shapes. The most obvious way to make this comparison would be to consider every point in turn as a binary digit and then convert each row back to a decimal value which could then be compared with a table of known values. However this has the disadvantage that we must actually check every individual point on the grid (64 points).

### A branching short cut

A quicker approach relies on the fact that each character can actually be detected by looking at a much smaller number of critical features of the



**Figure 8.2(a): Decision Tree for Alphabet.**

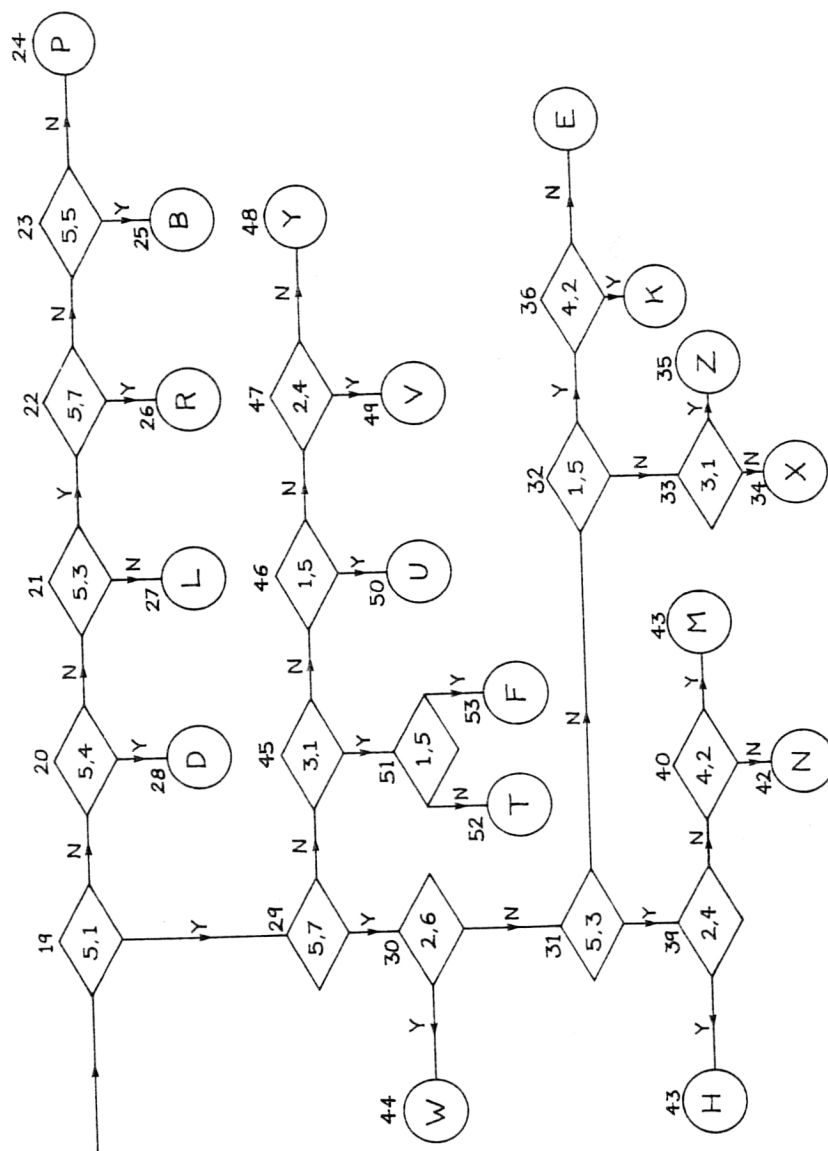


Figure 8.2(b)

pattern. For example, **Figure 8.2** gives a decision tree which will find all the capital letters of the alphabet using only 12 points (see **Figure 8.3**), and it is not even necessary to check all 12 in any particular case. If you follow each of the routes you will see that the maximum number of steps to be followed is 7, and that most letters are found in less than 5 steps (**Table 8.2**). This must obviously be quicker than comparing all 64 points!

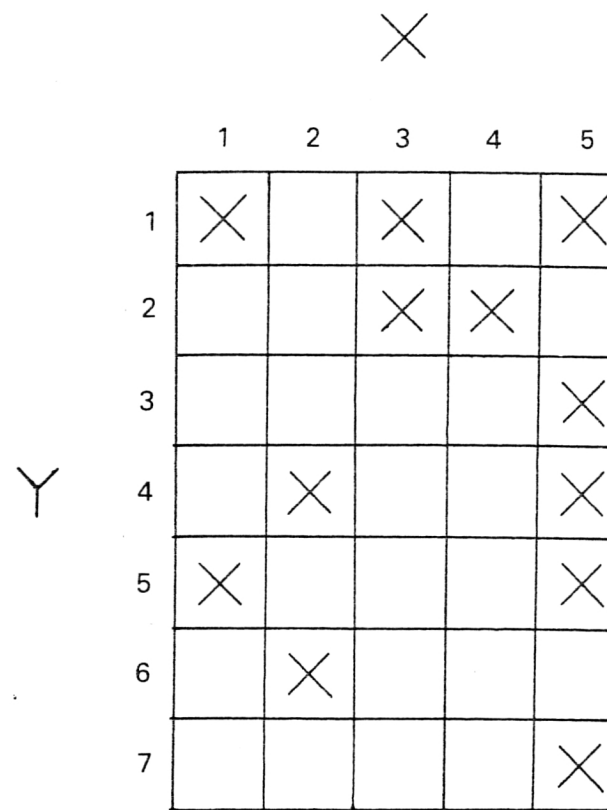


Figure 8.3: Points Used in Decision Tree.

To demonstrate how this approach works, we will simulate the action of the scanning head by producing a grid on the screen, on which you can construct characters.

The SET\_UP routine does the initial housekeeping, starting with the display.

Table 8.2: Numbers of Steps Required for Recognition of Each Character.

3 steps – I, D  
 4 steps – L, J, C, G, O, W  
 5 steps – S, A, Q, R, T, F, U, space  
 6 steps – P, V, Y, H  
 7 steps – B, M, N, E, K, X, Z

```
10 SET_UP

10000 DEFine PROCedure SET_UP
10010  SCREEN

10070 END DEFine SET_UP
```

The SCREEN is cleared and two vertical windows are set up. The left window (#2) is cleared to white, and the right window (#1) to green.

```
11000 DEFine PROCedure SCREEN
11010  MODE 4
11020  PAPER 0
11030  CLS
11040  WINDOW #2,270,200,26,16
11050  BORDER #2,3,7
11060  CSIZE #2,1,0
11070  CLS #2
11080  WINDOW #1,144,200,318,16
11090  BORDER #1,1,7
11100  CSIZE #1,1,0
11110  PAPER #1,5
11120  INK #1,0
11130  CLS #1
11140  BORDER #0,10,0
11150  INK #0,7
11160  CLS #0
11170 END DEFine SCREEN
```

The decision tree is held in a series of linked arrays where NB is the number of branches, LE\$(N) holds the names of the letters, C1(N) the X coordinate to be checked next, C2(N) the Y coordinate to be checked

next, N(N) the next element to use if the answer was 'no', and Y(N) the next element to use if the answer was 'yes'.

```
10020  AT #2,5,10 : PRINT #2,"LOADING DATA
      INTO ARRAY"
10030  TREE
10040  CLS#2

12000 DEFine PROCedure TREE
12010  RESTORE
12020  NB=53 : DIM LE$(NB),C1(NB),C2(NB)
      ,N(NB),Y(NB)
12030  FOR C=1 TO NB
12040    AT #2,15,12 : PRINT #2,C
12050    READ LE$(C) : READ C1(C) :
      READ C2(C) : READ N(C) : READ Y(C)
12060  END FOR C
12070  DATA 0,0,0,2,19
12080  DATA 0,0,4,3,10
12090  DATA 0,2,1,4,9
12100  DATA 0,4,0,5,8
12110  DATA 0,2,0,6,7
12120  DATA " ",0,0,0,0
12130  DATA "S",0,0,0,0
12140  DATA "J",0,0,0,0
12150  DATA "I",0,0,0,0
12160  DATA 0,4,3,11,14
12170  DATA 0,4,4,12,13
12180  DATA "C",0,0,0,0
12190  DATA "G",0,0,0,0
12200  DATA 0,4,6,18,15
12210  DATA 0,1,3,17,16
12220  DATA "A",0,0,0,0
12230  DATA "Q",0,0,0,0
12240  DATA "D",0,0,0,0
12250  DATA 0,4,0,20,29
12260  DATA 0,4,3,21,28
12270  DATA 0,4,2,27,22
12280  DATA 0,4,6,23,26
12290  DATA 0,4,4,24,25
12300  DATA "P",0,0,0,0
```

```

12310 DATA "B",0,0,0,0
12320 DATA "R",0,0,0,0
12330 DATA "L",0,0,0,0
12340 DATA "D",0,0,0,0
12350 DATA 0,4,6,45,30
12360 DATA 0,1,5,31,44
12370 DATA 0,4,2,32,39
12380 DATA 0,0,4,33,36
12390 DATA 0,2,0,34,35
12400 DATA "X",0,0,0,0
12410 DATA "Z",0,0,0,0
12420 DATA 0,3,1,38,37
12430 DATA "K",0,0,0,0
12440 DATA "E",0,0,0,0
12450 DATA 0,1,3,40,43
12460 DATA 0,3,1,42,41
12470 DATA "M",0,0,0,0
12480 DATA "N",0,0,0,0
12490 DATA "H",0,0,0,0
12500 DATA "W",0,0,0,0
12510 DATA 0,2,0,46,51
12520 DATA 0,0,4,47,50
12530 DATA 0,1,3,48,49
12540 DATA "Y",0,0,0,0
12550 DATA "V",0,0,0,0
12560 DATA "U",0,0,0,0
12570 DATA 0,0,4,52,53
12580 DATA "T",0,0,0,0
12590 DATA "F",0,0,0,0
12600 END DEFINE TREE

```

A  $5 \times 7$  GRID array (don't forget the zero elements) is DIMensioned to hold the points set information on the character which we will produce, and the cursor position is set to the top lefthand corner of this ( $X\% = 0$ ,  $Y\% = 0$ ).

```

10050 DIM GRID(4,6)
10060 X%=0 : Y%=0

```

Key prompts are displayed on the lefthand screen and then we are ready to use the EDITOR to design our character.

```

20 REPEAT CHARACTER
30 PRINT #2, "SPACEBAR to set point"
40 PRINT #2, "F1 to erase point"
50 PRINT #2, "F2 to clear screen"
60 PRINT #2, "F3 to decode"
70 EDITOR

90 END REPEAT CHARACTER

```

A block representation of the contents of the GRID array, with a flashing cursor to show your position, is produced in the righthand window (#1) by the EDITOR. The loop sets a block at the current coordinates ( $X\%$ ,  $Y\%$ ) to colour 2 (red), and then checks IF the corresponding GRID array element contains 1 (ie  $GRID(X\%, Y\%)$  is TRUE). If 1 is found then this block is set to colour 0 (black). Alternatively, ELSE sets the block back to colour 4 (green), so that there is no lasting effect. The rate of flashing is controlled by the delay value in the  $INKEY\$(N)$  check, and the sequence repeats until a key is pressed.

```

13000 DEFINE PROCEDURE EDITOR
13010 REPEAT LOOP
13020 BLOCK 28,28,(X%*28),(Y%*28),2
13030 IF GRID(X%,Y%) THEN
13040 BLOCK 28,28,(X%*28),(Y%*28),0
13050 ELSE
13060 BLOCK 28,28,(X%*28),(Y%*28),5
13070 END IF
13080 A$=INKEY$(5)
13090 IF A$="" THEN END REPEAT LOOP

```

When a key is pressed, the CODE of this key is taken and used in a series of IF-THEN tests. The X and Y coordinates are updated according to movement of the cursor keys and if the spacebar is pressed the colour of the current screen position is set to black and the corresponding GRID element is set to 1. If you make a mistake then Function key 1 erases the current position by resetting the colour to green, and resets the GRID element to 0. Note that checks have to be included to prevent movement beyond the edges of the grid.

```

13100 A=CODE(A$)
13110 IF A=192 AND X%>0 THEN X%=X%-1 :

```

```

13120      END REPEAT LOOP
13130      IF A=200 AND X%<4 THEN X%=X%+1 :
            END REPEAT LOOP
13140      IF A=208 AND Y%>0 THEN Y%=Y%-1 :
            END REPEAT LOOP
13150      IF A=216 AND Y%<6 THEN Y%=Y%+1 :
            END REPEAT LOOP
13160      IF A=32 THEN GRID(X%,Y%)=1 :
            BLOCK 28,28,(X%*28),(Y%*28),0 :
            END REPEAT LOOP
            IF A=232 THEN GRID(X%,Y%)=0 :
            BLOCK 28,28,(X%*28),(Y%*28),4 :
            END REPEAT LOOP

```

If your character design becomes a complete disaster then Function key 2 clears the screen in window #1, and then resets all the points in the GRID to 0.

```

13170      IF A=236 THEN
13180          CLS #1
13190          FOR C=0 TO 4
13200              FOR M=0 TO 6
13210                  GRID(C,M)=0
13220              END FOR M
13230          END FOR C
13240      END REPEAT LOOP
13250      END IF

```

Finally Function key 3 RETURNS to the READER PROCEDURE which decodes your design, or else the program loops back to the keycheck.

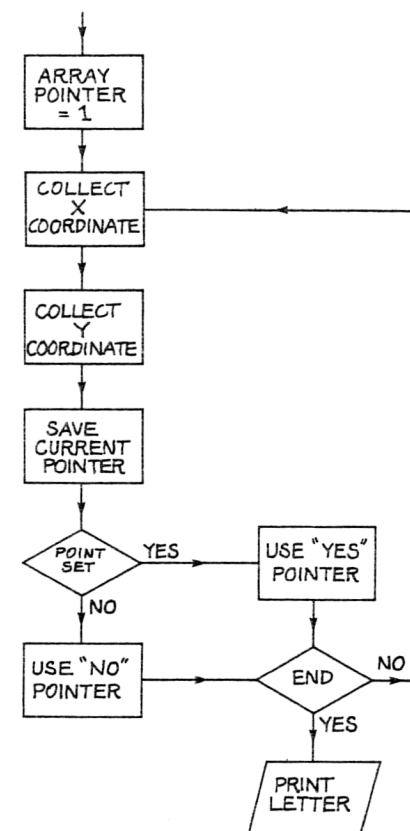
```

13260      IF A=240 THEN RETURN
13270      END REPEAT LOOP
13280      END DEFINE EDITOR

```

80      READER

In the READER PROCEDURE, the design produced is checked against the recognised patterns (see **Flowchart 8.1**). The array pointer, AP, is first set to 1 so that the search is started from the beginning. X and Y coordinates are read from the C1(AP%) and C2(AP%) elements pointed



Flowchart 8.1: READER PROCEDURE.

to, and the last position, LP%, pointer set equal to the current array pointer, AP%. The point colour, PC, at these coordinates is now determined by looking into the appropriate GRID array element. If this contains 1, then this point has been set and the 'yes' pointer, Y(AP%), must be followed. If any other value is found then the 'no' pointer, N(AP%), is followed. In either case a check is now made to see whether the element pointed to contains a 0 (which indicates the ultimate end of a branch), which shows that a character has been found. If so, the appropriate letter LES(LP%) is printed in window #0, and the display is held until a key is pressed, when a new cycle is initiated. As long as a higher value than 0 is found, this must be another branch point and so the program loops back and picks up the new values of C1(AP%) and

C2(AP%). To allow you to see which points have been checked these BLOCKS are set to red as they are found. Any points which were set but not tested will remain black.

```

14000 DEFine PROCedure READER

14020   AP%=1
14030   REPeat PIXEL_CHECK
14040     X%=C1(AP%) : Y%=C2(AP%) :
           LP%=AP%
14050     PC%=GRID(X%,Y%)
14060     IF PC% THEN AP%=Y(AP%) :
           ELSE AP%=N(AP%)

14080     IF AP% THEN
14090       BLOCK 28,28,(X%*28),(Y%*
           28),2
14100   END REPeat PIXEL_CHECK
14110   END IF
14120   CSIZE #0,3,1 : AT #0,6,0 :
           PRINT #0,"CHARACTER IS ";LE#
           (LP%); : CSIZE #0,0,0
14130   PRINT #2,\\ "PRESS A KEY TO
           CONTINUE"
14140   A$=INKEY#(-1)
14150   CLS#0 : CLS #1 : CLS #2
14160 END DEFine READER

```

So that you can see which part of the tree was actually followed, add these modifications which will print out the sequence of branches followed along the tree.

```

14010 PRINT #2,\\ "X axis", "Y axis",
      "point", "next"
14070 PRINT #2,\\ X%, Y%, PC%, AP%;

```

The disadvantage of this more rapid method (of only checking critical points) is that it will make a mistaken match if it encounters a shape that is not on the tree, whereas if all points are checked then no match will be found in such a case. Early optical character readers would only accept a single particular typeface, but the latest machines not only accept different styles of type, but actually learn the recognition rules for

themselves by means of a built-in expert system. You teach these by showing them a few pages of text and then entering these same characters via the keyboard. However we feel that it will still be a long time before anyone can produce a machine that can read *our* handwriting!



## CHAPTER 9

### An Intelligent Teacher

Another place where artificial intelligence can be particularly useful is in teaching programs. It is all very well having a program which tests a student's knowledge at random, but this is not how real human teachers work. As well as asking the questions, they keep an eye on the progress of the students, increase the difficulty of the questions as experience increases, and test them more rigorously on the types of problems with which they are having difficulties. For example, if a child takes a test involving addition, subtraction, multiplication and division, but only gets the division questions wrong, then it follows that the child should be given more division questions in the future to provide more practice.

Let's have a look at how we can introduce these 'human' qualities into a teaching program.

#### Questions and answers

We need to create random numbers to be used in the first question, which we will make an addition. Using RND(0 TO 10) will give numbers between 0 and 10.

```
10 SCREEN
20 REPEAT QUESTION
40   A%=RND(0 TO 10)
50   B%=RND(0 TO 10)

10000 DEFINE PROCEDURE SCREEN
10010   MODE 4
10020   CLS #0 : CLS #1 : CLS #2
10030 END DEFINE SCREEN
```

The computer adds these together and then goes on to an INPUT and CHECKING PROCEDURE.

```
60   C%=A% + B%
70   CHECK
```

First of all, CHECK must print the question and then INPUT your answer, IP%.

```
1000 DEFine PROCedure CHECK
1010   PRINT \A%; "+" ; B%; "=" ;
1020   INPUT IP%
```

Your answer must then be checked. If the answer, C%, is the same as your answer then CORRECT is printed, ELSE 'WRONG' is printed followed by the correct answer, and then the next question is asked.

```
1030   IF C%=IP% THEN
1040     PRINT "\"CORRECT"
1050     ELSE PRINT "\"WRONG, THE CORRECT
           ANSWER WAS "; C%
1060   ENDIF
1080 END DEFine CHECK

280   END REPEAT QUESTION
```

### Not a number?

If you experiment with this simple routine, you will find that it crashes if you enter a letter in place of a number (deliberately or accidentally). It would be a much more friendly teacher who refused to accept anything other than a number as INPUT, so we will use a GET PROCedure instead of that simple INPUT request. This INPUTs a string (IP\$), rather than a number, and first checks that the string is not empty (RETURN alone pressed). It then checks that the CODE of each character in the string (IP\$(N)) is a numeral (CODE between 42 and 56) before converting IP\$ to a simple variable (IP%) by coercion.

```
1020   GET
2000 DEFine PROCedure GET
2010   INPUT IP$
2020   IF IP$="" THEN GET
2030   FOR N=1 TO LEN(IP$)
2040     IF CODE(IP$(N)) < 43 OR CODE(IP$(N))
           > 57 THEN
2050       PRINT " ENTER A NUMBER!! ";
2060       GET
2070     END IF
2080   END FOR N
```

```
2090   IP%=IP$
2100 END DEFine GET
```

### Alternative rules

The other three rules of arithmetic (subtraction, multiplication and division) can be easily dealt with in the same way if we replace the '+' sign in line 1010 by a sign string, SG\$, which we can set to the appropriate character at the time. At the same time, as RND(0 TO 10) is common to all the calculations, we might as well DEFine this as a FuNction called PICK which RETurns an appropriate number.

```
1010   PRINT \A%; SG$; B%; "=" ;

3000 DEFine FuNction PICK
3020   RETurn RND(0 TO 10)
3030 END DEFine PICK
```

```
40   A%=PICK
50   B%=PICK
60   C%=A%+B% : SG$="+"
70   CHECK
100  A%=PICK
110  B%=PICK
120  C%=A%-B% : SG$="-"
130  CHECK
160  A%=PICK
170  B%=PICK
180  C%=A%*B% : SG$="*"
190  CHECK
220  A%=PICK
230  B%=PICK
240  C%=A%/B% : SG$="/"
250  CHECK
```

### Dividing by zero

As it stands, the program can crash if B% happens to be 0 when a division is selected. This can be simply fixed by always adding 1 on to B%, in this case:

230 B%=PICK+1

### Deleting decimals

We are using integer variables to keep us to round numbers, but of course a division may still produce a fractional answer, which you cannot enter correctly as IP% will be rounded down, eg:

$$3/2 = 1.5$$

but the program will accept 1, 1.5, 1.9 or any other number between 1 and 1.999. . . as correct.

To avoid producing decimals, A% needs to be a multiple of B%. To achieve this we calculate B% first and make A% equal to B% multiplied by a random number between 0 and 10.

220 B%=PICK+1  
230 A%=PICK\*B%

### Keeping a score

Now that we have the test itself working we need to consider how to keep a score. The simplest thing is to increment a tries variable, TR%, each time the GET PROCedure is used, and to increment a score variable, SC%, each time a correct answer is obtained.

```
10 SCREEN : TR%=0 : SC%=0
1040 PRINT "\"CORRECT" : SC%=SC%+1
2090 IP%=IP$ : TR%=TR%+1
```

Your current performance can now be shown by a SCORE PROCedure called at the end of CHECK.

```
1070 SCORE
4000 DEFine PROCedure SCORE
4010 PRINT "YOUR SCORE IS ";SC%,"/";TR%
4020 END DEFine SCORE
```

If you prefer the score as a percentage then amend line 4010 as follows:

```
4010 PRINT "YOU HAVE HAD ";(SC%/TR%)*100;
      "% CORRECT"
```

### How many questions?

The program will now ask one question of each type in sequence, ad infinitum. We can limit this by defining the number of questions, NQ%, as a variable.

```
10 SCREEN : TR%=0 : SC%=0 : NQ%=32
```

Each time a question is asked, NQ% is decreased by 1: when NQ% = 0 the test ends (after eight questions of each type have been answered).

```
2090 IP%=IP$ : TR%=TR%+1 : NQ%=NQ%-1
3010 IF NQ%=0 THEN PRINT "32 QUESTIONS
      ASKED"
```

### Shifting the emphasis

If we are going to bias the questions in favour of areas of difficulty, we need to keep a record of performance in each individual area. We therefore need separate variables for each type of question (AD% for addition, SU% for subtraction, MU% for multiplication, and DI% for division). These variables are defined in terms of one eighth of the total number of questions to be asked, NQ%.

```
10 SCREEN : TR%=0 : SC%=0 : NQ%=32 :
  AD%=NQ%/32 : SU%=NQ%/32 : MU%=NQ%/32
  : DI%=NQ%/32
```

Now if the correct answer, C%, is the same as your answer, IP%, then an increment variable, IN%, is set to -1, CORRECT is printed, and the routine returns. Otherwise IN% is set to 1 and WRONG is printed followed by the correct answer.

```
1040 PRINT "\"CORRECT" : IN%=-1
1050 ELSE PRINT "\"WRONG, THE CORRECT
      ANSWER WAS ";C% : IN%=1
```

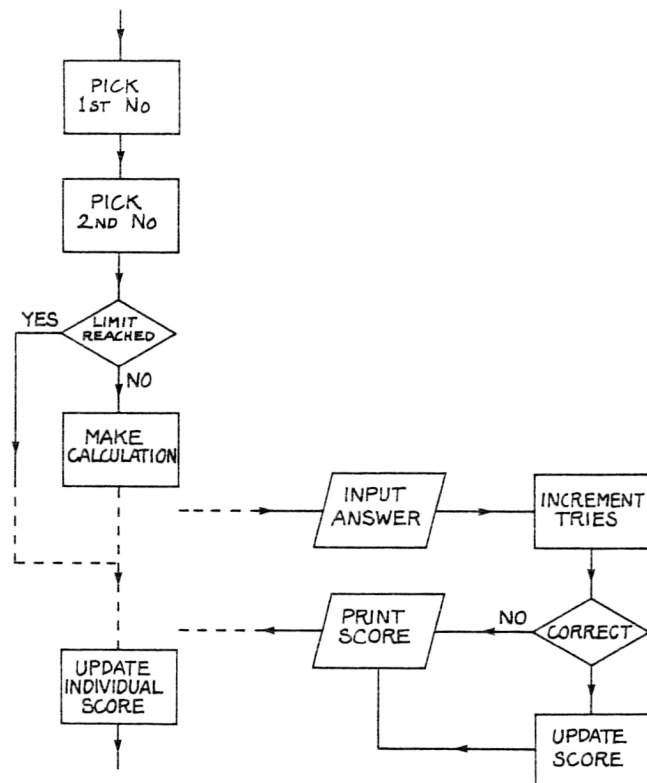
IN% is added to the appropriate individual number of questions variable — AD%, SU%, MU% or DI% — on returning from CHECK, producing an increase in this value if the answer was wrong, or a decrease if the answer was right.

```

70    CHECK : AD%=AD%+IN%
130   CHECK : SU%=SU%+IN%
190   CHECK : MU%=MU%+IN%
250   CHECK : DI%=DI%+IN%

```

Now we add a test to see whether all the questions of a particular type have not been correctly answered (eg  $AD\% > 0$ , see **Flowchart 9.1**). If all questions of a type have been correctly answered then no more of this type are asked as this section is jumped over.



Flowchart 9.1: Intelligent Teacher.

```

30    IF AD%>0 THEN
80    END IF
90    IF SU%>0 THEN
140   END IF
150   IF MU%>0 THEN
200   END IF
210   IF DI%>0 THEN
260   END IF

```

If the appropriate number of each type has been answered correctly —  $AD\% = 0$ ,  $SU\% = 0$ ,  $MU\% = 0$ ,  $DI\% = 0$  — then the program ends.

```

270   IF AD%+SU%+MU%+DI%=0 THEN PRINT
      "4 QUESTIONS OF EACH TYPE CORRECT"

```

Notice that you are no longer asked questions about areas in which you have correctly answered four questions without making any errors. If you make a mistake then  $AD\%$  (etc) will be increased, and therefore you will have to answer more than this number correctly before  $AD\%$  reaches 0.

### Degrees of difficulty

How about making the questions easier or harder according to how well you are doing (ie the values of  $AD\%$ ,  $SU\%$ ,  $MU\%$ , and  $DI\%$ )? So far the current values of  $A\%$  and  $B\%$  have always been between 0 and 10, as they were produced by  $RND(0 \text{ TO } 10)$ . We now need to bias the numbers produced for the questions towards higher values, if you are correct, and lower values if you are incorrect. At the same time we must ensure that you do not produce negative values if your performance is abysmal.

To start with, we need to modify the **PICK** Function so that the current value of the 'number of questions to be asked in each group' pointer ( $AD\%$ ,  $SU\%$ ,  $MU\%$  or  $DI\%$ ) is passed to it as  $X\%$ .

```

40    A%=PICK(AD%)
50    B%=PICK(AD%)

100   A%=PICK(SU%)
110   B%=PICK(SU%)

```

```

160      A%=PICK(SU%)
170      A%=PICK(SU%)

220      B%=PICK(DI%)+1
230      A%=PICK(DI%)

```

```
3000 DEFine FuNction PICK(X%)
```

The 'worst case' will be if you get all the questions wrong in the last group. In this case only four questions will be asked on the first three groups, leaving  $32 - (3 \times 4) = 20$  questions to be asked on the last group. In addition we must remember that X% (eg AD%) starts at a value of 4, so that the maximum value of X% which could be obtained is  $20 + 4 = 24$ .

We therefore set up a weighting variable, WT%, which is calculated by subtracting three times the number of questions to be asked in each group ( $3 \times AD\%$ ) from the total number of questions (NQ%) and adding back on the number of questions in the group AD% at the start.

$$WT\% = NQ\% - (3 \times AD\%) + AD\%$$

This is more simply expressed as:

$$WT\% = NQ\% - (2 \times AD\%)$$

```

10 SCREEN : TR%=0 : SC%=0 : NQ%=32 :
   AD%=NQ%/32 : SU%=NQ%/32 : MU%=NQ%/32 :
   DI%=NQ%/32 : WT%=NQ%-(2*AD%)

```

We now replace the fixed value of 10 by the difference between WT% and X%, by modifying the calculation in the PICK FuNction.

```
3020 RETurn RND(0 TO (WT%-X%))
```

To begin with,  $WT\% = 24$  and  $X\% = 4$  so numbers between 0 and 20 will be selected. If a correct answer is given, then X% is reduced to 3 and numbers between 0 and 21 will be chosen. After four correct answers, X% will not change (for this type of question) as it will have reached 0 and the line will be skipped. The last values will therefore be between 0 and 23.

But if the first answer is incorrect, X% will increase by 1 and the range of numbers produced reduced by 1 (0-19). In the 'worst case', X% will be increased 20 times to 24 and  $(WT\% - X\%)$  will fall to zero for both A% and B% (so you should be able to solve that particular problem!).

### What about words?

Although the example above deals solely with mathematical problems, there is absolutely no reason why the same technique cannot be used in dealing with more detailed textual questions and answers.

## CHAPTER 10

# Of Mice and Men

Mankind has been fascinated by mazes for centuries and the difficulties involved in finding the way out of (or to the centre of) a maze have featured prominently in mythology. More recently the theme has been taken up by the enthusiastic band of 'mouseketeers' who send their electronic micromice as their champions to do battle against the unknown. Whilst some may feel that these activities are trivial, we are sure that they would not object too much if somebody else was sent to check for radiation after a nuclear accident, or to explore the surface of some alien planet in their place!

Although short-range direct control of devices is possible, and a video link can allow an operator to 'see' his way, the delays involved in long-distance transmission pose considerable problems. It is of little value to see a picture showing that your multimillion pound exploratory probe is about to fall into a Martian crevasse if it has already fallen by the time you receive the picture! Autonomous intelligent devices will therefore always have their place. Although any real exploratory robotic device must be fitted with suitable sensors, dependent upon its environment and activities, and will require some reliable form of motive power, with our QL alone we can at least simulate some of the problems involved in finding your way around.

### Setting the scene

To begin with we set up a screen with three windows. On the right (#1) we will show the actual maze, on the left (#2) the contents of the MOUSE BRAIN are displayed, and at the bottom (#0) we have the current time and status.

#### 10 SCREEN

```
10000 DEFine PROCedure SCREEN
10010  MODE 4
10020  WINDOW #2,230,200,25,15
10030  BORDER #2,1,4
10040  PAPER #2,7
```



```

10050 INK #2,0
10060 CSIZE #2,1,0
10070 CLS #2
10080 WINDOW #1,230,200,258,15
10090 BORDER #1,1,4
10100 PAPER #1,0
10110 INK #1,7
10120 CSIZE #1,1,0
10130 CLS #1
10140 PAPER #0,0
10150 INK #0,0
10160 CSIZE #0,2,0
10170 CLS #0
10180 PAPER #0,7
10190 PRINT #0,"  MOUSE BRAIN
        MAZE      "
10200 END DEFine SCREEN

```

### Making the maze

We now need to produce a maze to travel through. Although we could generate one randomly it is rather more fun to design your own, and it makes it easier to create tests to determine which particular types of situation cause confusion. The actual maze is contained within a 37 by 33 array, but a copy of the contents of each array element is also displayed on window #1. Here each array element is represented in the window by a 6 by 6 pixel BLOCK, and before we start we will show the centre of the maze (18,16) as a green (colour 4) BLOCK. The start position is set in the top left corner at  $X\% = 1$ ,  $Y\% = 1$ .

#### 20 DESIGN

```

11000 DEFine PROCedure DESIGN
11010 DIM MAZE(37,33)
11020 X%=1 : Y%=1
11030 BLOCK 6,6,(18*6),(16*6),4

```

As long as no key is pressed, we loop around flashing a non-destructive cursor, which alternates between green (colour 4) and the present colour in the current maze coordinates.

```

11040 REPeat LOOP
11050 BLOCK 6,6,X%*6,Y%*6,4

```

```

11060 BLOCK 6,6,X%*6,Y%*6,MAZE(X%,Y%)
11070 A%=INKEY$(2)
11080 IF A%="" THEN END REPeat LOOP

```

When a key is pressed, the four cursor directions are checked. As long as you remain within set limits in the array the X and Y coordinates are updated, and the screen cursor moves (without leaving a trail).

```

11090 A=CODE(A%)
11100 IF A=192 AND X%>1 THEN X%=X%-1 :
        END REPeat LOOP
11130 IF A=200 AND X%<35 THEN X%=X%
        +1 : END REPeat LOOP
11160 IF A=208 AND Y%>1 THEN Y%=Y%-1
        : END REPeat LOOP
11190 IF A=216 AND Y%<31 THEN Y%=Y%
        +1 : END REPeat LOOP

```

To form the maze we need to mark out a path in the maze array for the mouse to follow. We also show this on the screen as white (colour 6) BLOCKs. So that it is easy to alter the maze by swapping white BLOCKs for black (0), we DEFine a PATH PROCedure to which we can pass a parameter indicating the colour to be used. Remember that both the actual maze and the screen display must be updated.

```

12000 DEFine PROCedure PATH (COLOUR)
12010 MAZE(X%,Y%)=COLOUR
12020 BLOCK 6,6,X%*6,Y%*6,COLOUR
12030 END DEFine PATH

```

White BLOCKs are produced by pressing CTRL and an arrow key, and black erasing BLOCKs by pressing ALT and an arrow key.

```

11110 IF A=193 AND X%>1 THEN PATH 0
        : X%=X%-1 : END REPeat LOOP
11120 IF A=194 AND X%>1 THEN PATH 6
        : X%=X%-1 : END REPeat LOOP
11140 IF A=201 AND X%<35 THEN PATH 0
        : X%=X%+1 : END REPeat LOOP
11150 IF A=202 AND X%<35 THEN PATH 6
        : X%=X%+1 : END REPeat LOOP

```

```

11170      IF A=209 AND Y%>1 THEN PATH 0
          : Y%=Y%-1 : END REPEAT LOOP
11180      IF A=210 AND Y%>1 THEN PATH 6
          : Y%=Y%-1 : END REPEAT LOOP
11200      IF A=217 AND Y%<31 THEN PATH 0
          : Y%=Y%+1 : END REPEAT LOOP
11210      IF A=218 AND Y%<31 THEN PATH 6
          : Y%=Y%+1 : END REPEAT LOOP

```

Should your maze start to look like a disaster area, then pressing SHIFT and F1 will RUN the program so that you can start from scratch again!

```

11220      IF A=234 THEN RUN

```

Finally SHIFTed F2 will RETURN from DESIGN so that the mouse can start his search. (Note that the only condition to be satisfied in the maze is that the start point ( $X\% = 1$ ,  $Y\% = 1$ ) must be connected to the centre in some way.)

```

11230      IF A=238 THEN RETURN
11240      END REPEAT LOOP
11250 END DEFINE DESIGN

```

### Finding the route

We can now send our mouse into action looking for the cheese in the centre of the maze. We need to give him a memory, which will be the same size as the maze array, set him the start position (1,1), and reset the clock with SDATE, so that we can time his progress.

```

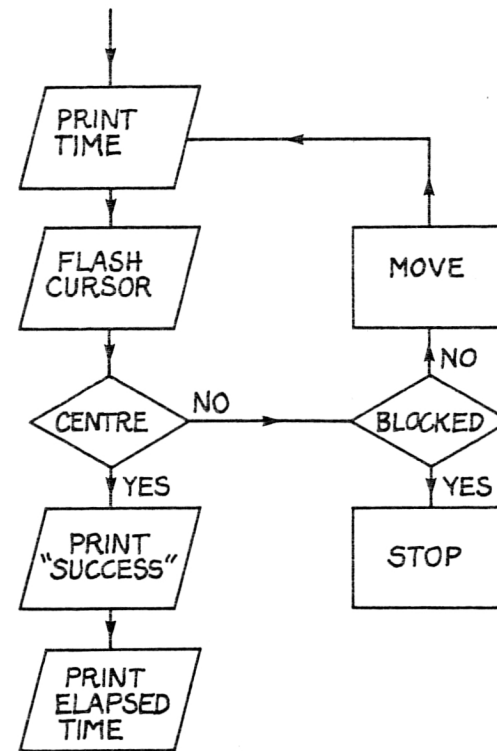
30  REPEAT RESTART

40  DIM MEMORY(37,33) : X%=1 : Y%=1

60  SDATE 1984,0,0,0,0,0

```

The movement of the mouse falls within a loop (see **Flowchart 10.1**). The first action in this is to PRINT the last five characters of DATE\$ (ie the minutes and seconds part). Note that you cannot slice DATE\$ itself, but must convert it to the temporary variable D\$ first.



Flowchart 10.1: Starting Movement.

```

70  REPEAT MOVEMENT
80  D$=DATE$
90  D$=D$(16 TO)
100 AT #0,16,0 : PRINT #0,D$

180 END REPEAT MOVEMENT

```

The array element at the start coordinates in the MEMORY is set to green (colour 4), and a flashing cursor on window #2 in the corresponding position is produced by the TRACK PROCEDURE. This takes three parameters (X and Y coordinates and the colour to be used for the BLOCK).

```

110     MEMORY(X%,Y%)=4
120     TRACK X%,Y%,0
130     TRACK X%,Y%,MEMORY(X%,Y%)

```

```

1000 DEFine PROCedure TRACK (X1,Y1,C)
1010     BLOCK #2,6,6,(X1*6),(Y1*6),C
1020 END DEFine TRACK

```

### A bull's eye?

We can easily check whether the centre has been reached by checking the appropriate coordinates (18,16). When (or maybe that should be IF) the centre is reached, then the journey time is reported, and you have three options. Pressing 'N' RUNs the program so that you can design a new maze. Pressing 'C' clears the screen on window #2 and then returns you to RESTART for another attempt at the same maze (as only the MEMORY array, and not the MAZE array, is reset). Pressing any other key RESTARTs on the same maze without clearing the screen, so that any differences in the points which are checked in the next attempt are more obvious.

```

140     IF X%=18 AND Y%=16 THEN CENTRE

```

```

2000 DEFine PROCedure CENTRE
2010     PRINT #0," HE REACHED THE CENTRE OF
        THE MAZE\" IN ";D$(1 TO 2);"
        MINUTES AND ";D$(4 TO 5);" SECONDS"
2020     A$=INKEY$(-1)
2030     IF A$="N" THEN RUN
2040     IF A$="C" THEN CLS #2 : END REPEAT
        RESTART
2050     END REPEAT RESTART
2060 END DEFine CENTRE

```

### Which way?

The mouse must take a look to see where it is possible to move. The next position to be examined is determined by adding X and Y Decision values (XD% and YD%) on to the current coordinates. To begin with, we will set XD% to 0 and YD% to 1, so that the mouse will always try to move down.

```

50     XD%=0 : YD%=1

```

```

150     IF MAZE(X%+XD%,Y%+YD%)=0 THEN
        STOP

```

```

170     X%=X%+XD% : Y%=Y%+YD%

```

RUN the program, draw a simple vertical line, and start the mouse by pressing SHIFT F2. You will see that he moves down until he reaches the end of the line, when he STOPS. So far so good but we now have to decide what he should do when the next position does contain 0.

### Coping with corners

Your first thought might be to reverse the direction if a wall is hit (inverting XD% and YD% by multiplying them by -1) but of course that would only send the mouse shuttling back and forth along the line ad infinitum. If he is to be able to make a turn to a new heading then he must check around to find out more about his surroundings. Four FuNctions are defined to cope with each of the four possible directions (left, right, up, down). Each of these works in basically the same way, using an UNKNOWN PROCedure to find out what is in the next possible position. So far we have only looked at the maze and have not put any information into the mouse memory. As long as nothing has been put into a MEMORY location then this will still be 0. We must therefore copy the appropriate maze information into MEMORY, as well as making a TRACK to show that we have looked here. If the location has already been checked then UNKNOWN has no effect. Now if any of the direction FuNctions find an unchecked MEMORY location then we RETURN immediately without CHECKing the other possibilities. This means that LEFT has priority over RIGHT, which has priority over UP, which has priority over DOWN. Note that this means that the mouse will always make the same decisions, and that XD% and YD% are only updated if the Colour Code variable (CC) is matched, indicating a pathway is present (see Flowchart 10.2).

```

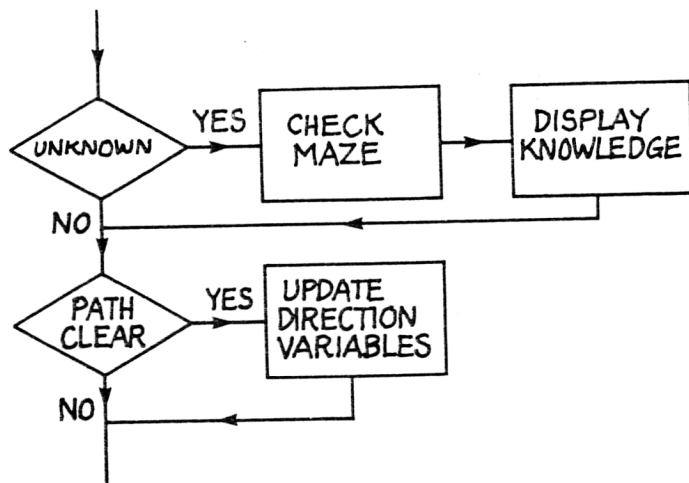
150 DUMMY=CHECK

```

```

3000 DEFine FuNction CHECK
3020     CC=6
3060     IF LEFT THEN RETURN 0
3070     IF RIGHT THEN RETURN 0

```



Flowchart 10.2: Coping with Corners.

```

3160 IF UP THEN RETURN 0
3170 IF DOWN THEN RETURN 0
3240 RETURN -1
3250 END DEFINE CHECK

```

```

4000 DEFINE PROCEDURE UNKNOWN (X1,Y1)
4010 IF MEMORY(X1,Y1)=0 THEN
4020 MEMORY(X1,Y1)=MAZE(X1,Y1)
4030 TRACK X1,Y1,MEMORY(X1,Y1)
4040 END IF
4050 END DEFINE UNKNOWN

```

```

5000 DEFINE FUNCTION LEFT
5010 UNKNOWN X%-1,Y%
5020 IF MEMORY(X%-1,Y%)=CC THEN XD%=-1 :
      YD%=0 : RETURN -1
5030 RETURN 0
5040 END DEFINE LEFT

```

```

6000 DEFINE FUNCTION RIGHT
6010 UNKNOWN X%+1,Y%
6020 IF MEMORY(X%+1,Y%)=CC THEN XD%=1 :
      YD%=0 : RETURN -1
6030 RETURN 0
6040 END DEFINE RIGHT

```

```

7000 DEFINE FUNCTION UP
7010 UNKNOWN X%,Y%-1
7020 IF MEMORY(X%,Y%-1)=CC THEN XD%=0 :
      YD%=-1 : RETURN -1
7030 RETURN 0
7040 END DEFINE UP

```

```

8000 DEFINE FUNCTION DOWN
8010 UNKNOWN X%,Y%+1
8020 IF MEMORY(X%,Y%+1)=CC THEN XD%=0 :
      YD%=1 : RETURN -1
8030 RETURN 0
8040 END DEFINE DOWN

```

If you try that out with a winding pathway such as that shown in **Figure 10.1**, you will see that only LEFT and RIGHT are actually checked most of the time, as the program RETURNS before UP and DOWN are reached.

### Cutting the checks

As things are, LEFT, RIGHT and UP must all be checked before DOWN, whereas it would be more sensible if we reduced the amount of checking done by introducing a bit more logic. Only LEFT and RIGHT need to be CHECKED when XD% is 0 (ie the mouse was already moving UP or DOWN), and only UP and DOWN CHECKED when YD% was 0 (ie he was already moving LEFT or RIGHT, see **Flowchart 10.3**).

```

3030 IF XD%=0 THEN
3060 IF LEFT THEN RETURN 0
3070 IF RIGHT THEN RETURN 0
3120 END IF
3130 IF YD%=0 THEN
3160 IF UP THEN RETURN 0
3170 IF DOWN THEN RETURN 0
3220 END IF

```

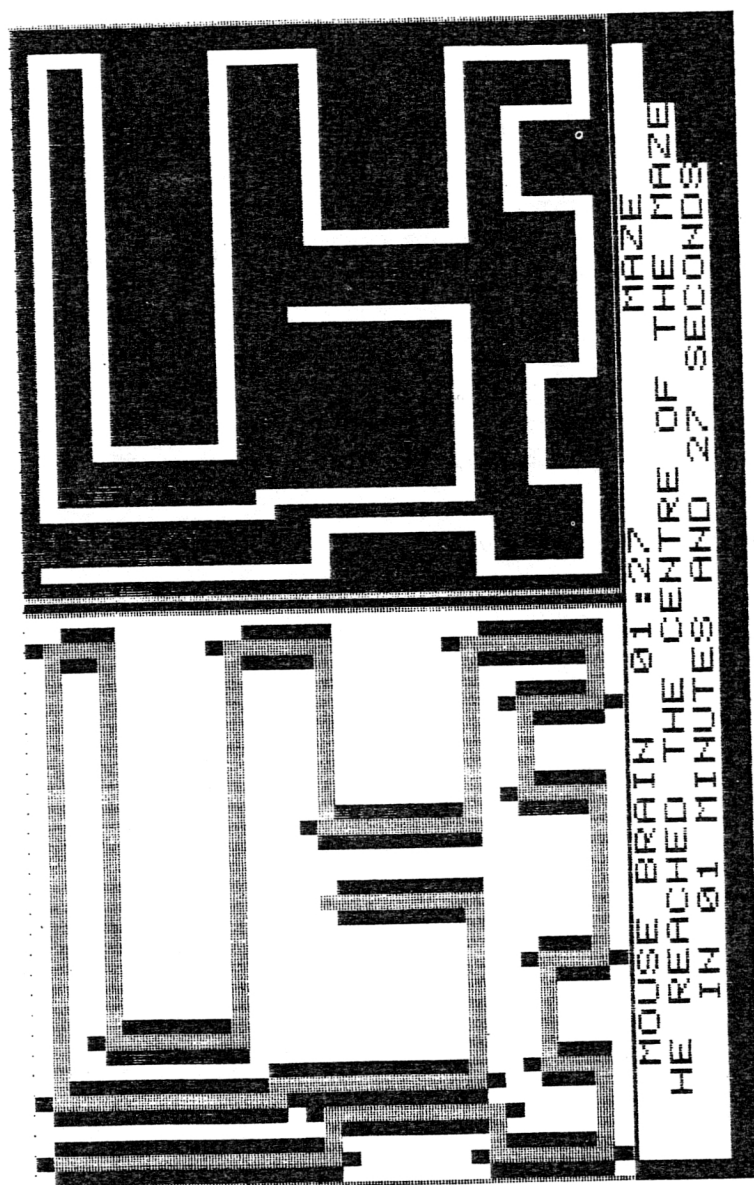
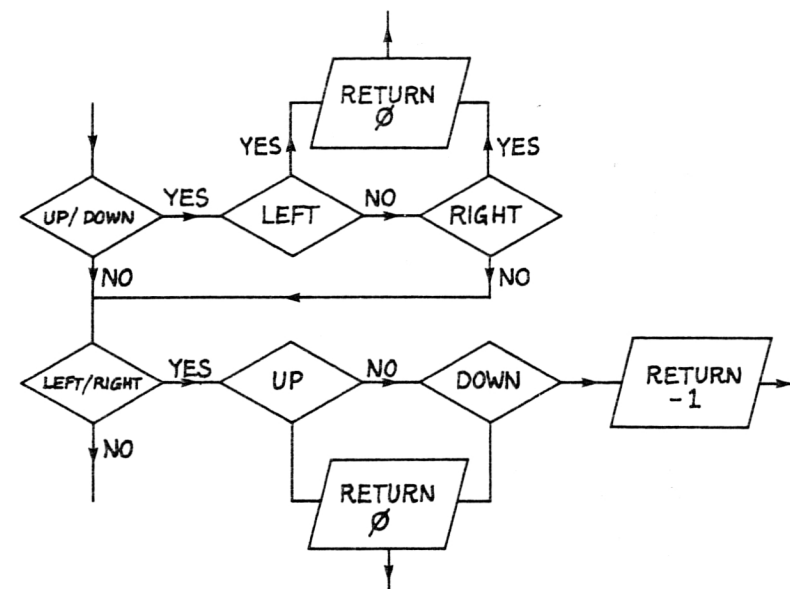


Figure 10.1: Coping with Corners.



Flowchart 10.3: Cutting the Checks.

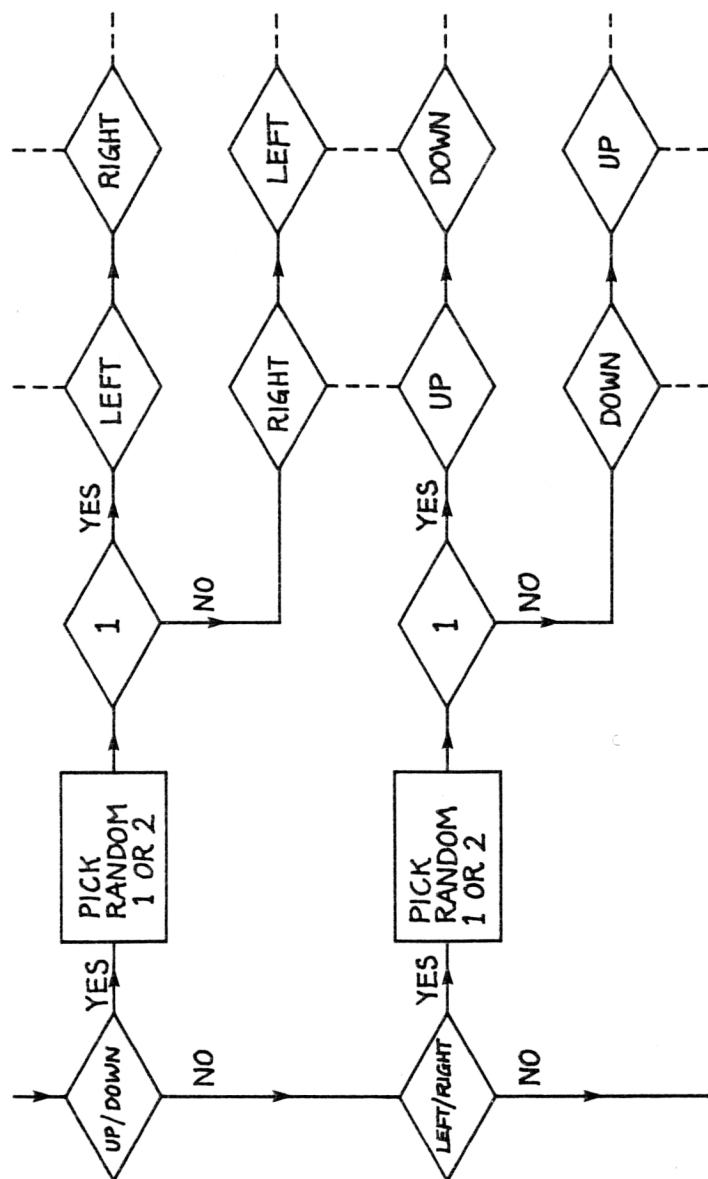
### Jinxing at junctions

Our mouse will now move round corners OK, but if he reaches a junction then he will always move LEFT or UP, if they are possible, as these possibilities are always checked first. Such predictable behaviour can get him going round in circles, so it would be better if we introduced random selection from the two possible directions in each case, so that he does not always give the same priority. LR% (LEFT–RIGHT) and UD% (UP–DOWN) variables are chosen at random as 1 or 2, and used to reverse the order in which the directions are checked (see Flowchart 10.4).

```

3000 DEFine FuNction CHECK
3020   CC=6
3030   IF XD%=0 THEN
3040     LR%=RND(1 TO 2)
3050     IF LR%=1 THEN
3060       IF LEFT THEN RETURN 0
3070       IF RIGHT THEN RETURN 0
3080     ELSE
3090       IF RIGHT THEN RETURN 0

```



Flowchart 10.4: Jinxing at Junctions.

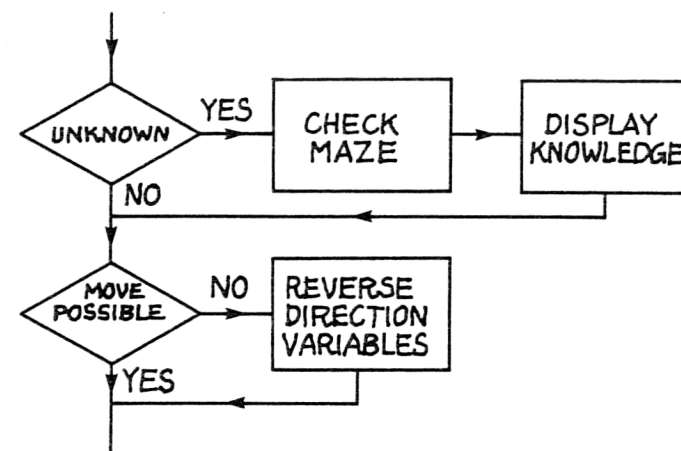
```

3100     IF LEFT THEN RETURN 0
3110     END IF
3120     END IF
3130     IF YD%=0 THEN
3140         UD%=RND(1 TO 2)
3150         IF UD%=1 THEN
3160             IF UP THEN RETURN 0
3170             IF DOWN THEN RETURN 0
3180         ELSE
3190             IF DOWN THEN RETURN 0
3200             IF UP THEN RETURN 0
3210         END IF
3220     END IF
3240     RETURN -1
3250 END DEFINE CHECK
  
```

If you try that out several times on a maze containing a square (eg **Figure 10.2**) then you will notice that now the same path is not always followed.

### Backtracking

Now IF all the checks are negative, AND the next maze position contains 0 (indicating a wall rather than an unchecked position) then the mouse's only alternative is to go into reverse (multiplying the current XD% and YD% variables by -1 — see **Flowchart 10.5**).



Flowchart 10.5: Backtracking.



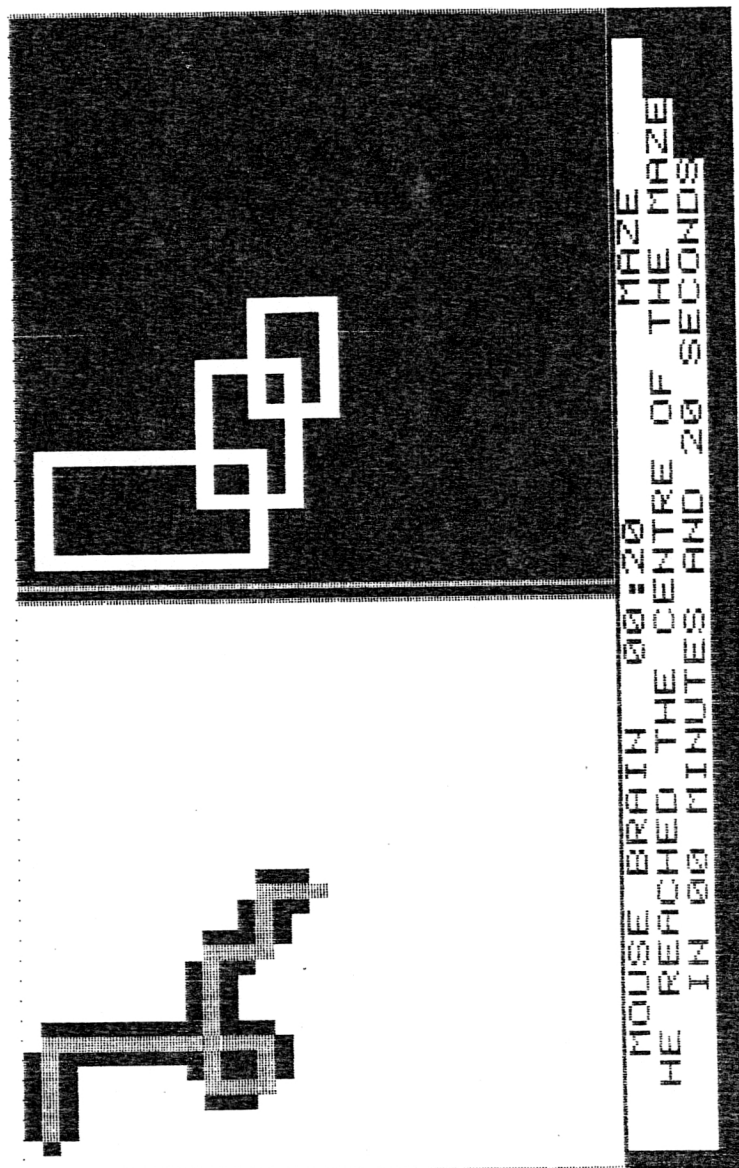


Figure 10.2: Jinxing at Junctions.

```

150 UNKNOWN X%+XD%,Y%+YD%
160 IF CHECK AND MAZE(X%+XD%,Y%+YD%)=0
    THEN XD%=XD%*-1 : YD%=YD%*-1

```

He will now reverse when a dead end is reached, and continue to check until an alternative pathway is found.

### Where no mouse has gone before

It seems sensible to give a higher priority to parts of the maze which have not already been visited, as the odds in favour of success are biased towards the unknown.

In the program so far the areas he has not visited, but which are valid paths, are marked as white (colour 6), and those visited once are marked in the MEMORY as green. We can arrange so that when the mouse backtracks the trail colour is changed from green to red. This is easily done by adding a FOR loop which alters the value of CC in the CHECK routine. Now, as the loop decrements by 2 each time it repeats, white is checked for first, followed by green (4) and, as a last resort, red (2). Once the first match is found we RETURN so that we now have effectively produced the colour priority white > green > red.

```

3020 FOR CC=6 TO 2 STEP-2
3230 END FOR CC

```

### Speed merchant?

Although the progress of the mouse is now 'slow but sure', you might consider that it would be better not to bother to make detailed checks on the surroundings IF the path ahead was shown to be clear (ie colour 6). Adding the following line speeds the mouse up considerably, as he now only makes checks when that is absolutely necessary (Figure 10.3).

The disadvantages with this approach are that he becomes more predictable and that he will always go straight on at a junction when that is possible. In particular, side branches will not be found without backtracking. How important that is in specific situations depends on the deviousness of your maze, which of course is up to you!

```

3010 IF MEMORY(X%+XD%,Y%+YD%)=6 THEN RETURN 0

```

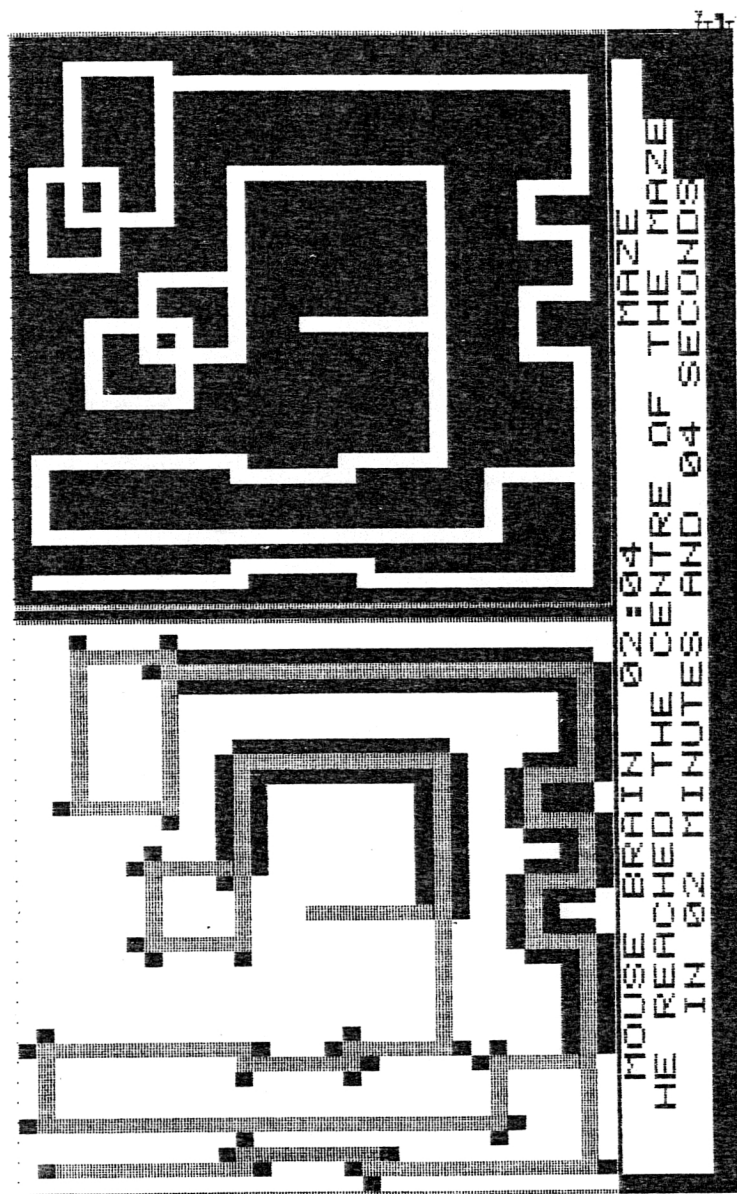


Figure 10.3: Speed Merchant.

## CHAPTER 11

### Intelligent Use of Archive

The ARCHIVE intelligent database program included with the QL is a powerful tool for manipulating records and extracting information. It is a good example of a 'state of the art' intelligent program, but to use it most effectively you must understand clearly how it operates.

Now whole books could (and no doubt will) be written on ARCHIVE alone, so we will concentrate here on two aspects only. The first of these is how to use the commands to extract the required information correctly, and the second is how you could produce a more user-friendly shell for the 'British Standard Idiot' to use.

Start by loading the ARCHIVE program from microdrive with:

```
lrun mdv1_boot
```

Now a DIRectory of microdrive 1 should show the sample database file included with the program (GAZET.DBF).

```
dir "mdv1_"
```

(Note that quotation marks are needed to access the microdrive from within ARCHIVE.)

To make life easy we will use this GAZETeer database to explore the potential of ARCHIVE, so first of all we need to activate it with:

```
look "mdv1_gazet"
```

At this point, DISPLAY will show the layout and the first record in the file (see Figure 11.1).

```
display
```

To move on through the file you can use:

```
next
```

and if you are browsing through the file then repeated typing of 'next' can

```

Logical name      : main
country$          : AFGHANISTAN
continent$        : ASIA
capital$          : KABUL
languages$        : PUSHTU, DARI
currency$         : AFGHANI
pop               : 19.5
gdp               : 110
area              : 657

```

Figure 11.1: First Record.

be avoided by pressing F5, which repeats the last text in the keyboard buffer, and then ENTER. Although this feature is of limited value in this particular case, it is a boon when a long sequence of commands are involved.

To retrace your steps use:

back

Or for major leaps:

first

or:

last

### Finding a match

The simplest matching command available is FIND, which searches all fields of a record for a match with the input string.

For example:

find "europe"

will display the record for ALBANIA, which is the first occurrence of EUROPE.

It is important to notice that the lower case input (europe) was matched with the upper case (EUROPE), as FIND is case-independent.

To find the next match with the same string, CONTINUE is used rather than NEXT.

Thus:

continue

will produce the record for AUSTRIA.

One feature of FIND is that it looks for a match with any part of the record, and takes no account of surrounding characters. This can sometimes be a problem:

find "asia"

continue

produces first AFGHANISTAN but then AUSTRALIA, which is of course in AustralASIA rather than simply ASIA.

On the other hand, this can be useful if you only want to match part of a record. For example 'languages' often contains the name of more than one language, but you will still find matches with any part of this.

Thus:

find "english"

continue

continue

continue

will eventually retrieve the BOTSWANA record where languages\$ is 'ENGLISH, SETSWANA', rather than simply 'ENGLISH'.

Another good example would be finding which countries use some form of dollar (\$) as currency.

find "\$"

picks AUSTRALIA (with the AS\$) as the first match.

Sometimes it is advantageous to deliberately truncate an input word to obtain all required matches. If you compare:

find "english"

with

find "engl"

you will see that the latter produces significantly more matches.

### Searching specifically

SEARCH is a more specific, but also more powerful, command which

requires that a specified condition is satisfied. It acts only on specified fields, and is case-dependent, so that:

search continent\$ = "asia"

finds no matches but:

search continent\$ = "ASIA"

does, whilst:

search continent\$ = "AMERICA"

finds nothing as 'AMERICA' is always preceded by some qualifying letter such as 'N'.

Although you cannot search to find which countries use the dollar as the unit of currency (as the dollar string is usually embedded) you can easily search to determine whether a number is greater or less than a specified value. Thus whilst SEARCH is basically more exact it allows you to be less precise in some ways!

Hence:

search area <2

gives

HONG KONG (1)  
MARTINIQUE (1)

and

search area >10000

produces only

U.S.S.R (22402)

Strings can be compared as well as numbers:

search country\$ >"C"

gives

CAMEROUN

(the first country beginning with a character sequence further up in alphabetical order than the letter specified, 'C').

More than one condition to be satisfied may be specified. For example how many countries in Africa use French as their sole language?

search continent\$ = "AFRICA" and  
languages\$ = "FRENCH"

BENIN  
CENTRAL AFRICAN REP.  
CHAD  
COMORO IS.  
CONGO  
GUINEA  
IVORY COAST  
MALI  
REUNION  
TOGO

What about asking which of those use the CFA FR as currency as well? The obvious way to do that is to tack another condition on:

search continents\$ = "AFRICA" and  
languages\$ = "FRENCH" and  
currency\$ = "CFA FR"

CENTRAL AFRICAN REP.  
CHAD  
COMORO IS.  
CONGO  
IVORY COAST  
TOGO

### Selecting records

A more effective way of dealing with this type of problem may be to SELECT subsets of records. The total number of records in the GAZET file can be found by:

print count ( )

where the answer is 152.

You can select countries in Africa only with:

```
select continent$ = "AFRICA"
```

Now

```
print count ( )
```

gives only 49, and the system acts as if only those records existed. Hence:

```
search languages$ = "FRENCH"
```

will now find the French-speaking-only countries in Africa, or you could select just these with:

```
select languages$ = "FRENCH"
print count ( )
```

leaving only ten countries in the file. (There is no reason why this selection cannot be done in a single step.)

### Putting things in order

If you look at the list of French-speaking African countries above, you will see that they are in alphabetical order. This is purely fortuitous as the whole GAZET file was originally set in alphabetical order by country, but this ORDER can be easily modified.

Thus:

```
order area;a
```

puts them into ascending order by area as

```
COMORO IS.
REUNION
TOGO
BENIN
GUINEA
IVORY COAST
CONGO
CENTRAL AFRICAN REP.
MALI
CHAD
```

and

```
order capital$a
```

puts them into ascending order according to the name of the capital (with ABIDJAN in the IVORY COAST top of the list).

Whether selection or searching is quicker really depends on what particular information you are trying to extract.

To retrieve the whole file use:

```
reset
```

### Partial matches

In one of the examples above we SELECTed the African countries which have French as their sole language — but what about those who have both French and other languages? Remember that FIND is not specific — so why not select the countries in AFRICA, as before, and then find 'FRENCH'.

```
select continent$ = "AFRICA"
```

```
find "FRENCH"
```

```
continue
```

### Using PROCedures

So far we have only scratched the surface of the potential of ARCHIVE as we have only used direct commands, which have simply located and displayed entire matching records. However, using the PROCedure editor we can tailor more impressive sequences for specific tasks. To enter the editor type:

```
edit
```

and when you are prompted for a PROCedure name enter:

```
cont1
```

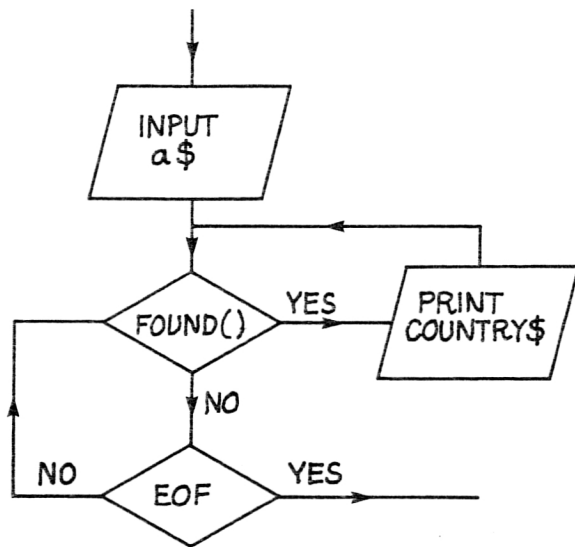
and then the following PROCedure lines which carry out an automatically repeated FIND.

```
proc cont1
  cls
  input "which continent? ";a$
```

```

find a$
while found()
  print country$; " "
  continue
endwhile
endproc

```



Flowchart 11.1: PROC cont1.

A search string (a\$) is input in reply to the 'which continent?' question, and a FIND for this is continued while FOUND( ) is true (see **Flowchart 11.1**). Now FOUND( ) is zero when FIND was unsuccessful, providing a suitable loop-ending test. Notice that we have specified that only country\$ is printed, rather than the whole record, so that only the requested information is displayed. Once the PROCedure is entered you can press ESC to return to ARCHIVE and then run your new PROCedure by simply entering its name:

```
cont1
```

When the prompt appears enter 'asia' when a list showing only the names of countries in ASIA will appear — but note that AUSTRALASIA has also been found.

To restrict the match to 'ASIA' you can search instead. The only line that needs to be changed is:

```
find a$
```

which becomes

```
search continent$ = a$
```

Of course only upper case will now be matched, which can be rather a nuisance. One way round this is always to convert your input into upper case, and as this is a common requirement we might as well define it as a new PROCedure called GET. Enter the editor as before and then use F3 and 'N' to create a new PROCedure.

```

proc get
  input a$
  let a$=upper(a$)
endproc

```

The input line in CONT1 now needs to be replaced by:

```
print "which continent? "; : get
```

if both 'ASIA' and 'asia' are to be accepted. To go back to your old CONT1 PROCedure, press ESC followed by SHIFT and TABULATE, and then edit the line.

### A more friendly (inter)face

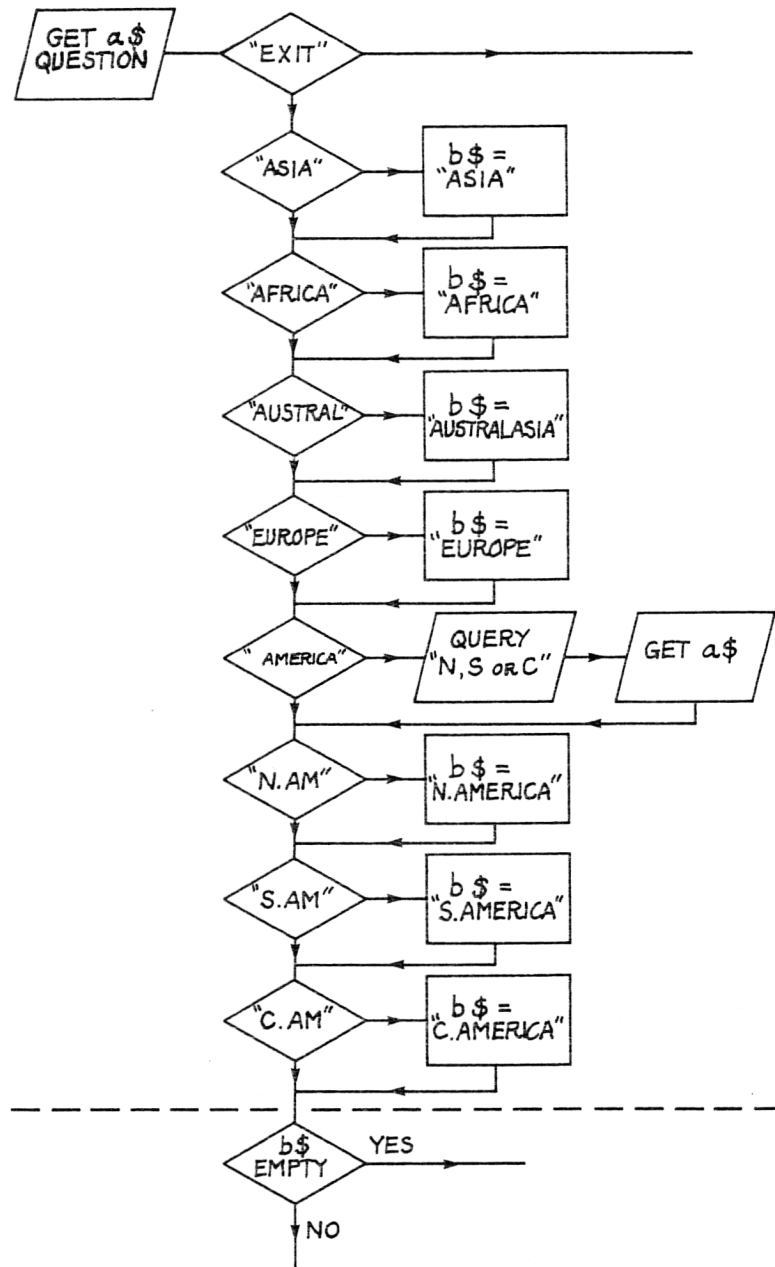
So far you have to type the string to be matched exactly as it appears in the record — but it would be more user-friendly if you could be rather vaguer. Who knows, you might even be able to convince your sceptical relations that computers are worth talking to!

We will define a new PROCedure called TELL, which provides an outer 'shell' so that the user never has to worry about the nitty-gritty details of what is actually being done within ARCHIVE (**Flowchart 11.2**).

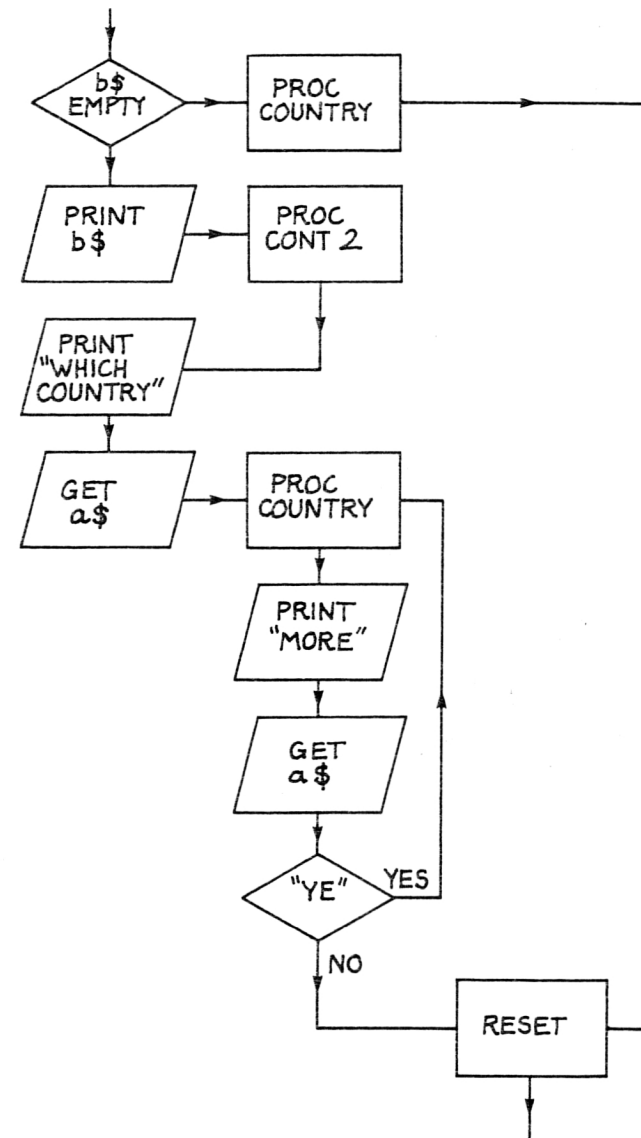
A major feature is that it uses an INSTR search of your input against keywords to try to find out what you want, rather than simply accepting it as given.

Now when you use TELL you are prompted to make an input, which can contain anything you like. This is checked for key sequences of



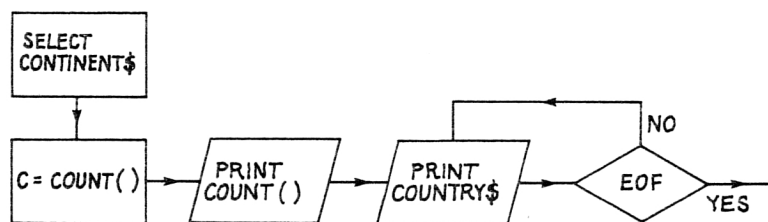


Flowchart 11.2(a): Proc tell (i).

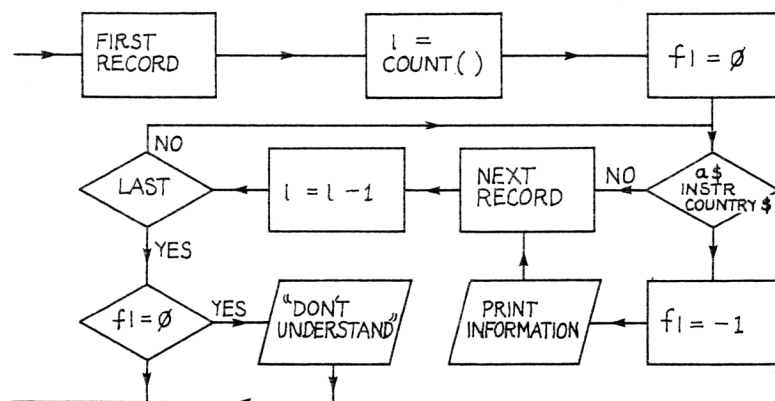


Flowchart 11.2(b): PROC tell (ii).





Flowchart 11.2(c): PROC cont2.



Flowchart 11.2(d): PROC country.

characters, such as ASIA, AFRICA, AUSTRAL, and EUROPE. If you now enter any sentence containing one of these key phrases which describe continents, a search will be made for the appropriate match.

Thus:

ASIA  
ASIAN  
ASIATIC  
AFRICA  
AFRICAN  
AUSTRALIA  
AUSTRALIAN  
AUSTRALASIA  
AUSTRALASIAN  
EUROPE  
EUROPEAN

WORLD INFORMATION

PLEASE ENTER YOUR QUESTION

? PLEASE WILL YOU GIVE ME SOME INFORMATION ABOUT AMERICA

DO YOU MEAN  
N.AMERICA  
S.AMERICA  
OR C.AMERICA  
N.AMERICA  
N.AMERICA

There are 2 countries in N.AMERICA

CANADA U.S.A

Which country would you like to know more about?  
CANADA

CANADA is in N.AMERICA  
It has a population of 23.1 million,  
spread over 9976000 sq km  
(a population density of 2.32/sq km)  
The capital is OTTAWA  
and the currency is the CAN.\$

Do you wish to have any  
more information about N.AMERICA  
YES PLEASE

Which country would you like to know more about  
U.S.A.

U.S.A. is in N.AMERICA  
It has a population of 215.3 million  
spread over 9363000 sq km  
(a population density of 22.99/sq km)  
The capital is WASHINGTON  
and the currency is the \$

Do you wish to have any  
more information about N.AMERICA  
NO

Figure 11.2: Sample Printout from TELL PROCEDURE.

will all be accepted.

In the case of AMERICA a more mug-trapped approach is used as the GAZET file divides this into three distinct areas, which must be specified precisely. Note that this depends on finding a space before AMERICA.

If a continent name is not found (b\$ = "") then a check is made to see whether the input is the name of a country by the COUNTRY PROCEDURE, which checks for a match between your input and all the country\$ variables in the file. Note that this uses an odd 'logic' as your input may contain any number of words, whereas the variable in the record is only a single phrase. Thus we look for country\$ in your input (a\$) rather than vice versa.

If a match is found then a number of variables are picked from this record and presented neatly embedded in text. Note that this information also contains the DERIVED population density figure which was not in the actual record. The WHILE L (ie count( )) loop will check all records in the file, so that you can ask about more than one country at a time, but the INKEY( ) check gives you an easy way out if you can't stand the graunching sound from the microdrives any longer. If no match is found then you are advised of this and you return to the calling PROCEDURE.

Where the name of a continent is found the CONT2 PROCEDURE is called, which selects the records of all those countries in this area, and prints out their names. You are now asked 'which country would you like to know more about', and the COUNTRY PROCEDURE is used to find this as before. The WHILE R loop allows you to repeat your searches on this continent.

Figure 11.2 gives a sample printout of the program.

This approach is obviously rather more friendly, but you can see that the hard work has had to be done in advance, and that all the INSTR checking inevitably slows things down. Perhaps you would like to try adding more facilities to the program so that you can check more than one field at a time.

#### ARCHIVE TELL PROCEDURE

```
proc tell
  reset
  mode 0,6
  let dummy=-1
  while dummy
    cls
    print
    print "WORLD INFORMATION"
    print
```

```
print "PLEASE ENTER YOUR QUESTION"
print
let b$=""
print
print "? ";
get
if a$="EXIT"
  print "BYE FOR NOW"
  let dummy$=getkey()
  mode 1,6
  reset
  return
endif
if instr(a$,"ASIA")>0
  let b$="ASIA"
endif
if instr(a$,"AFRICA")>0
  let b$="AFRICA"
endif
if instr(a$,"AUSTRAL")>0
  let b$="AUSTRALASIA"
endif
if instr(a$,"EUROPE")>0
  let b$="EUROPE"
endif
if instr(" "+a$," AMERICA")>0
  print
  print "DO YOU MEAN?"
  print "N.AMERICA"
  print "S.AMERICA"
  print "OR C.AMERICA?"
  print
  get
endif
if instr(a$,"N.AM")>0
  let b$="N.AMERICA"
endif
if instr(a$,"S.AM")>0
  let b$="S.AMERICA"
endif
if instr(a$,"C.AM")>0
  let b$="C.AMERICA"
endif
```

```

if b$<>""
  print b$
  cont2
  let r=-1
  while r
    print
    print "Which country would you
    like to know more about? "
    get
    print
    country
    print "Do you wish to have any"
    print "more information about ";b$
    get
    if instr(a$,"YE")=0
      let r=0
    endif
  endwhile
  else
    country
  endif
  let dummy$=getkey()
  reset
endwhile
endproc

```

## ARCHIVE CONT2 PROCEDURE

```

proc cont2
  select continent$=b$
  let c=count()
  print
  print "There are ";c;" countries in";b$
  print
  while c
    if c/4=int(c/4)
      print
    endif
    print country$;" ";
  next
  let c=c-1
endwhile
endproc

```

## ARCHIVE COUNTRY PROCEDURE

```

proc country
  first
  let l=count()
  let fl=0
  while l
    if INSTR(a$,country$)>0
      let fl=-1
      print
      ink 4
      print country$;" is in ";continent$
      print "It has a population of ";pop;
      " million,"
      print "spread over ";area;"000 sq
      km"
      print "(a population density of ";
      print str(pop/(area/1000),0,2);
      "/sq km)"
      print "The capital is ";capital$
      print "and the currency is the ";
      print currency$
      ink 7
    endif
  next
  let l=l-1
  if inkey()<>""
    return
  endif
endwhile
if fl=0
  ink 2
  paper 7
  print "I don't understand what you
  mean"
  ink 7
  paper 0
endproc

```

## CHAPTER 12

### A Naturally Expert Salesman

In the previous chapters we have dealt from first principles with various aspects of artificial intelligence, but in this final chapter we have linked together many of these individual ideas into a single complete program. The original intelligent program was the famous ELIZA, which was a pseudo-psychiatrist program written to send up a particular style of psychiatric therapy, but we have resisted the temptation to follow this lead any further and have opted instead to produce a synthetic replacement for the computer salesman.

Although ELIZA-type programs which will hold a 'conversation' with you are not uncommon, this particular program is rather unusual in that it combines processing of natural language with an expert system to produce a result which should both understand your natural language requests and make suggestions which take into account your requirements, the strengths and weaknesses of particular machines in 20 different areas, and a number of hard commercial facts like cost and profit margin!

Enough words and values have already been included to make the program interesting, but you can easily customise it by adding your own ideas to the DATA. (We take no responsibility for the values included so far, which are for demonstration purposes only, or the views on particular machines expressed by the program.) The program itself basically follows the methods described earlier in the book and the functions of the various PROCedures, FuNctions, variables and arrays are given in **Table 12.1**.

**Table 12.1(a): Variables and Arrays.**

#### SIMPLE VARIABLES

QP%	no. of question sentences
Q%	no. of questions
R%	no. of rules
OB%	no. of objects
AJ%	no. of adjectives
AV%	no. of adverbs
LI%	no. of likes

DL%	no. of dislikes
NJ%	no. of negative adjectives
NV%	no. of negative adverbs
HM%	no. of cheap/expensive
BB%	bank balance
CO%	no. of computers
FE%	no. of features
CT%	no. of cost ratings
CS%	no. of cost suggestions
EX%	no. of excuses
HI%	no. of high price suggestions
LO%	no. of low price suggestions
LD%	like/dislike
TC%	total cost
TP%	total profit
OF%	object flag
NP%	negative/positive
M%	marker
OM%	object marker
S1%	AND position
S2%	BUT position
CM%	comma position
SP%	search position
ST%	search start
PH%	selected question phrase
IS%	search position
RU%	rule update value
XX%	cheap/expensive
TX%	selected excuse
PT%	selected credit warning
TS%	cost of most expensive match
BS%	cost of least expensive match
HI%	most expensive match
LO%	least expensive match
SE%	most/least
SL%	cost phrase selector

## ARRAYS

OB\$(OB%,10)	objects
AJ\$(AJ%,6)	adjectives
NJ\$(NJ%,7)	negative adjectives

AV\$(AV%,6)	adverbs
NV\$(NV%,6)	negative adverbs
LI\$(LI%,7)	likes
DL\$(DL%,7)	dislikes
Q\$(Q%,20)	question objects
QP\$(QP%,16)	question sentences
CR(Q%)	cost rate
PR(Q%)	profit rate
IC(Q%)	total cost
IP(Q%)	total profit
HM\$(HM%,20)	cheap/expensive
R(R%)	desire rule
CO\$(CO%,30)	computer names
FE(CO%,FE%)	feature names
C(CT%)	cost ratings
CS\$(CS%,100)	cost suggestions
EX\$(EX%,100)	excuses
HI\$(HI%,100)	high messages
LO\$(LO%,100)	low messages

Table 12.1(b): PROCedures and FuNctions.

## PROCEDURES

SCREEN	set windows
TITLE	prints title
SET_UP	READs DATA, sets variables
PICK_QUESTION	selects question phrase (PH\$)
LOOK_AT	looks for '@' marker in PH\$
LOOK_AND	looks for '&' marker in PH\$
JOIN_1	forms the question with the question objects at the end
JOIN_2	forms the question with the question objects embedded
AND_OR_BUT	updates the rules depending upon the word preceding the AND_OR_BUT in your input
YES_PRESENT	updates the rules if YES_PRESENT in your input
NO_PRESENT	updates the rules of NO_PRESENT in your input

NT_PRESENT	updates the rules if NT_PRESENT in your input
DOUBLE_NEGATIVE	checks for a DOUBLE_NEGATIVE in your input
LIKES	checks for LIKES verbs in your input
DISLIKES	checks for DISLIKES verbs in your input
OBJECTS	checks for OBJECTS in your input
ADVERBS	checks for ADVERBS (positive)
NEGATIVE_ADVERBS	checks for NEGATIVE_ADVERBS
ADJECTIVES	checks for ADJECTIVES (positive)
NEGATIVE_ADJECTIVES	checks for NEGATIVE_ADJECTIVES
CHEAP_EXPENSIVE	prints cheap or expensive message
RULE_UPDATE	updates rules
COST_PROFIT	calculates total cost and profit
SPENDING	compares with bank balance
PICK_COMPUTER	selects matching computer

## FUNCTIONS

FIND_slash	searches for a slash '/' in PH\$
FIND_ask	searches for an asterisk '*' in PH\$
FIND_comma	searches for a comma ',' in IN\$
FIND_AND	searches for 'AND' in IN\$
FIND_BUT	searches for 'BUT' in IN\$

## Making conversation

The format of the program is that you are asked for your views on each of a number of possible features in turn (the exact wording of the question being PICKed at random from a selection of available QUESTION phrases). Note that the keyword or phrase is inserted into the sentence where necessary and that the correct conjugation is applied, by FIND\_slash, LOOK\_at, LOOK\_and, FIND\_ask, JOIN\_1 and JOIN\_2.

The screen display is divided into five horizontal windows (**Figure 12.1**) which are dedicated to specific purposes. Window #0, at the bottom,

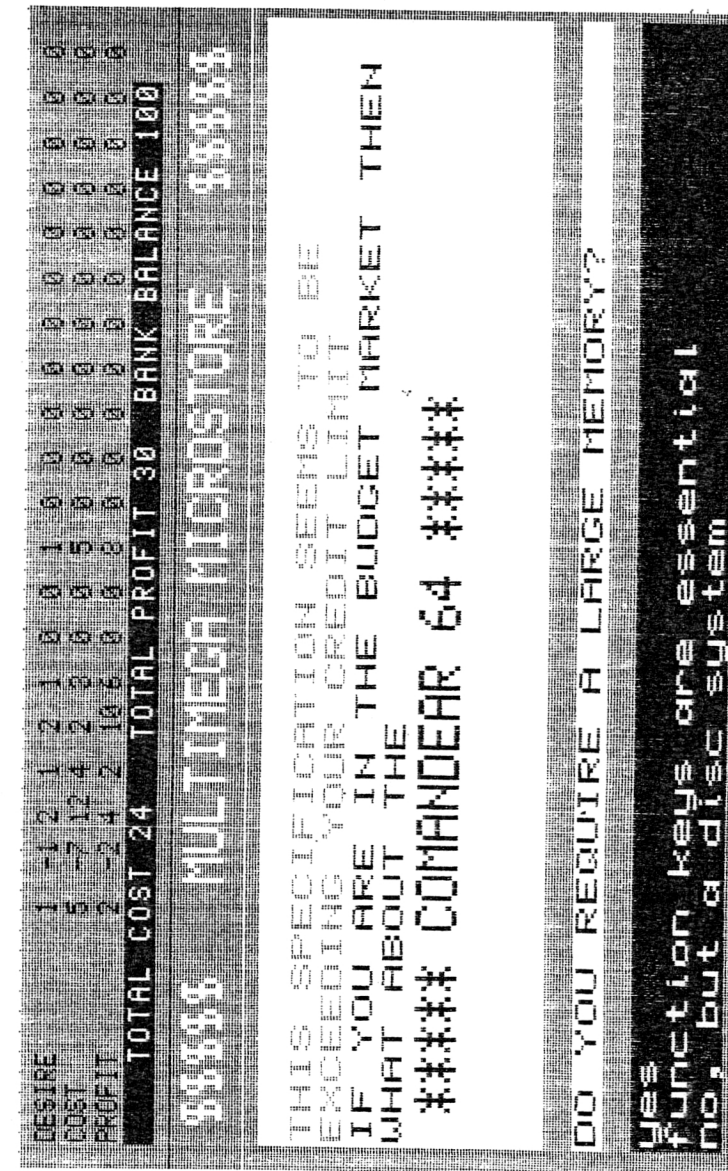


Figure 12.1: Workings of Salesman's Mind.

receives your input sentences, which are entered in response to the prompting questions which appear on the small window (#3) just above it. Above this is the largest window (#1) on which a whole series of relevant comments appear. Window #4 simply contains an advertisement for the 'Multimedia Microstore', whilst finally the top window (#2) displays at least part of the contents of the salesman's brain, to show the rules on which he is basing his judgement. Of course this may give you more insight into a salesman's motives than usual.

Your input is examined in detail for a series of keywords, and a DESIRE RULE array is updated according to your requests. (You actually see the rule arrays being updated in the top screen window.) Note that many of the keywords are truncated so that one check can be made for a number of similar words, and a test is included to check that the matching string is at the start of a word, to reduce mismatches (eg LIKE in DISLIKE). If you are obsessed with one particular feature (eg 16-BIT PROCESSOR) then the salesman does not take you too seriously as this is obviously a 'buzz word' gleaned from the last month's issue of 'People's Computer News'.

The simplest test is whether there is YES\_PRESENT or NO\_PRESENT which add or subtract 1 from the DESIRE RULE for that feature, and if you mention the name of the OBJECTS (eg GRAPHICS) then a further 1 is added to the DESIRE RULE. In addition, using 'positive' ADJECTIVES or ADVERBS also adds to this rule, whilst a NEGATIVE\_ADJECTIVE or NEGATIVE\_ADVERB subtracts from this rule. Separating the words into different classes allows you to make more than one change to this rule at the same time.

Thus:

YES	adds 1
YES BASIC	adds 2
YES BASIC NECESSARY	adds 3
YES GOOD BASIC NECESSARY	adds 4
Whilst:	
NO	subtracts 1
and	
NO MEMORY	subtracts 2

Furthermore verbs are grouped as LIKES and DISLIKES: the latter reverse the action of the rest of the words.

Thus:

I DETEST MACRODRIVES subtracts 1

Both NO\_PRESENT and NT\_PRESENT are recognised and most DOUBLE\_NEGATIVES are interpreted correctly.

Thus:

I DON'T LIKE SOUND subtracts 2

I DON'T DISLIKE SOUND adds 2

If anything appears at the start of a sentence and is followed by a comma then FIND\_COMMA usually cuts it off and it is effectively ignored.

Thus:

NO, I DON'T WANT GOOD SOUND subtracts 3

The exception is when AND\_OR\_BUT are included, when both parts of the sentence are acted on independently.

Thus if the question is:

DO YOU WANT GRAPHICS?

and the answer is:

NO, BUT I WANT GOOD SOUND

then 1 is subtracted from the graphics rule and 2 added to the sound rule.

If the program does not find any keywords in the input then it politely asks you to try again:

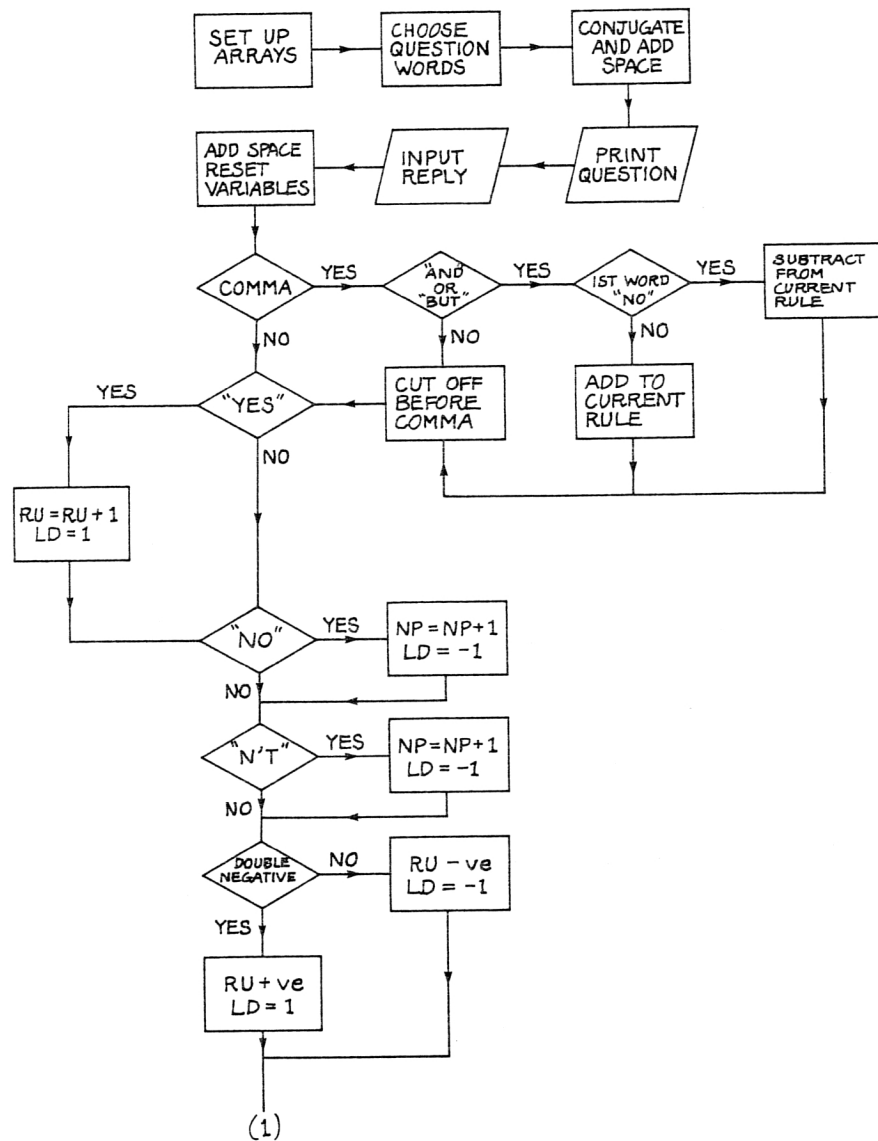
PARDON, EXCUSE ME BUT . . .

The program can only cope with one feature at a time so if you try to ask for SOUND and GRAPHICS, for example, at the same time, you will get a request for a repeat of the question.

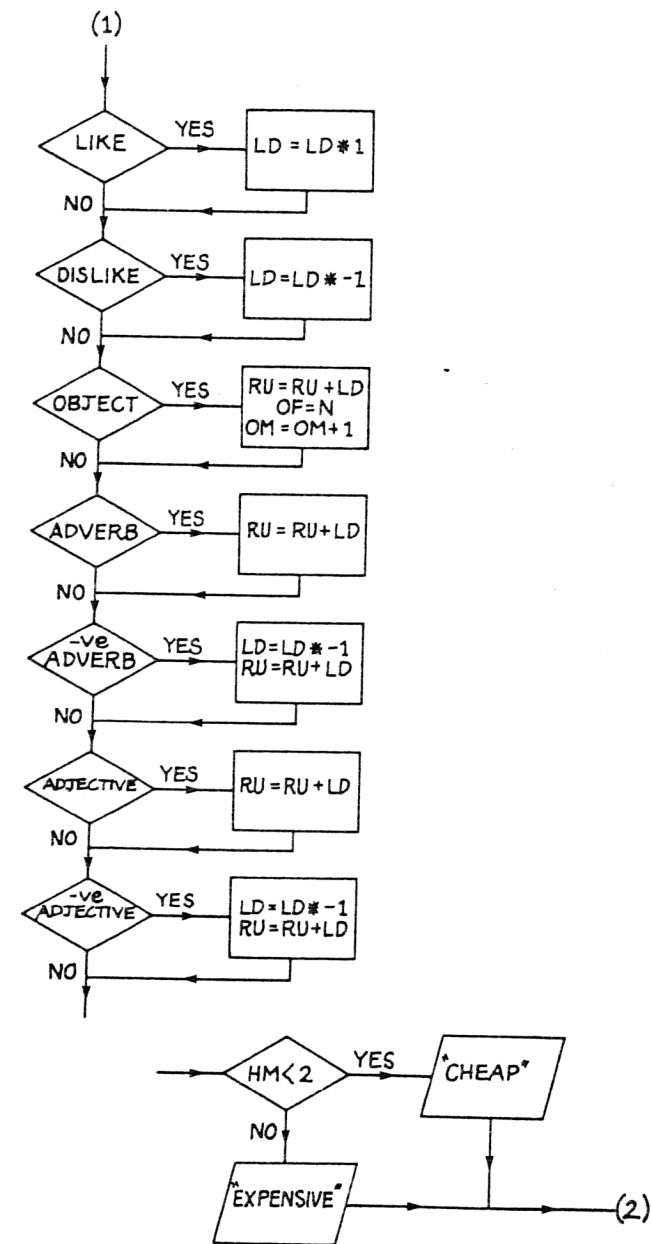
HANG ON — ONE THING AT A TIME

However it is possible to make comments about single features that you are not being asked about at the time, and these entries will still update the rules (as in the BUT example above).

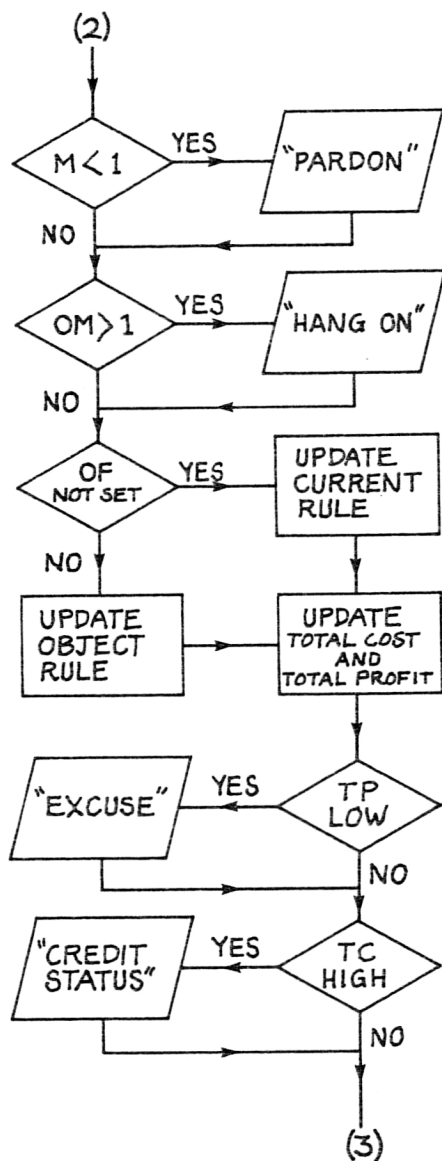




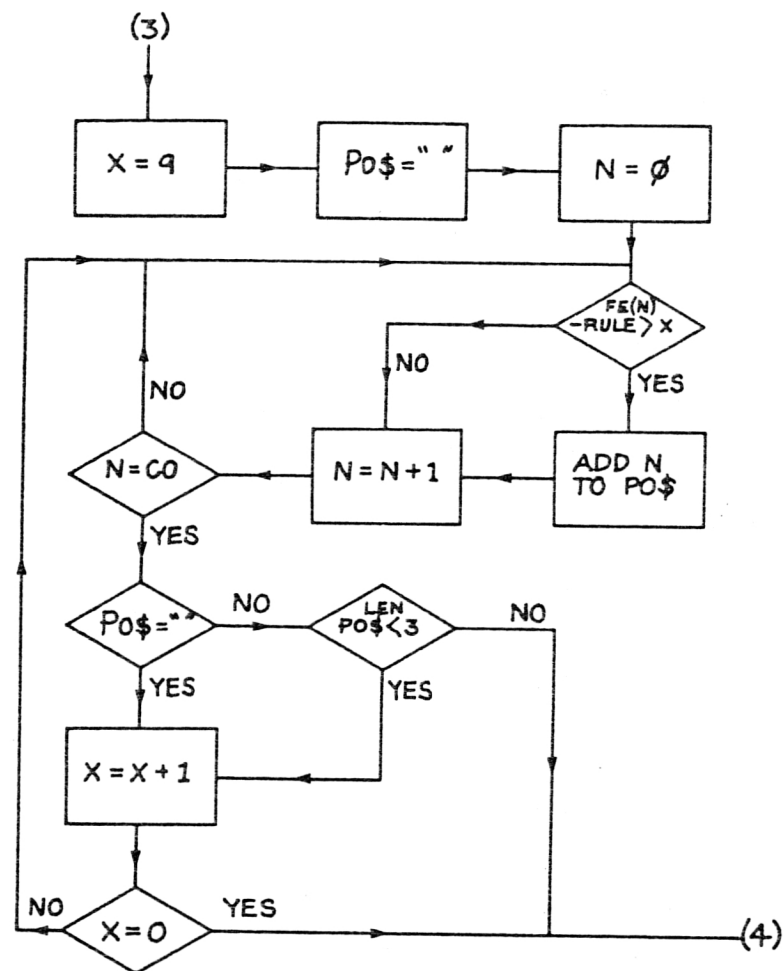
Flowchart 12.1(a): Computer Salesman.



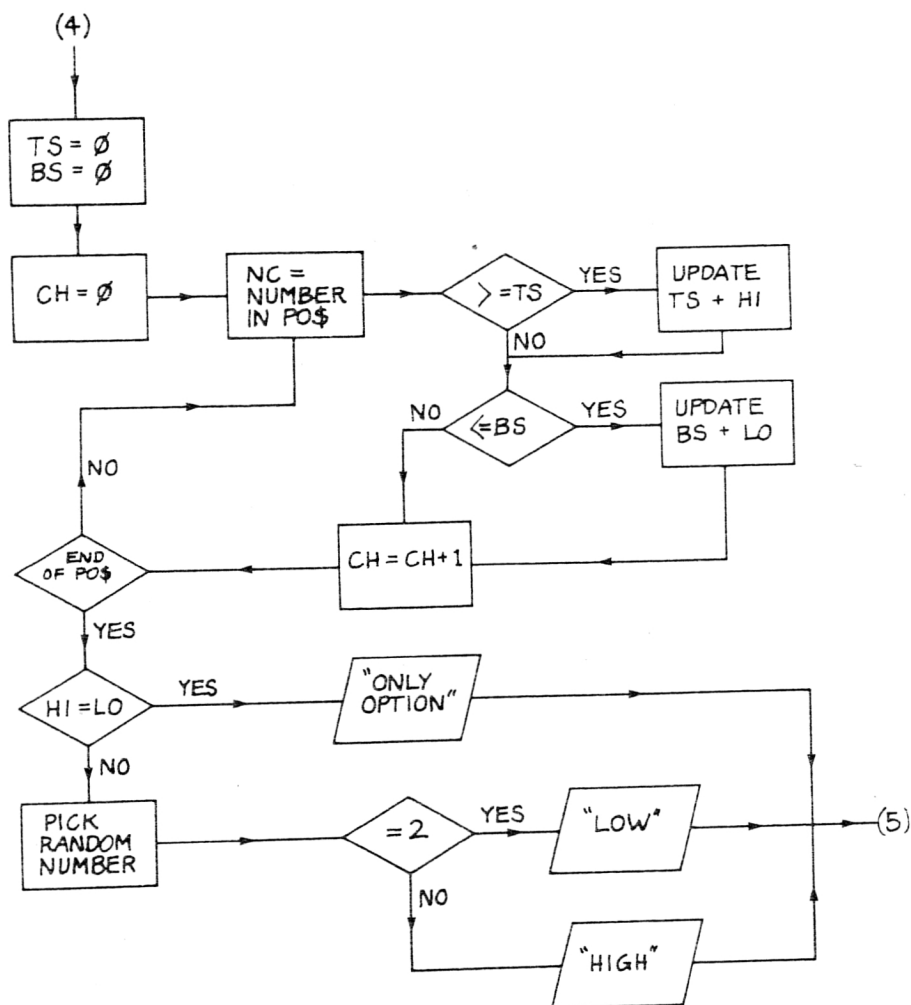
Flowchart 12.1(b)



Flowchart 12.1(c)



Flowchart 12.1(d)



Flowchart 12.1(e)

## Decisions

Once the input has been decoded as far as possible we move to RULE\_UPDATE. In addition to the DESIRE RULE array there are two other arrays which are linked to this. The first is the COST RULE, which gives an indication of the cost of this particular option, and the second is the PROFIT RULE which indicates to the salesman how much effort it is worth putting into selling this feature. The values for these last two arrays are produced by multiplying the content of the corresponding rule array element by factors entered originally in the DATA (see Table 12.2) where the format is:

(phrase describing feature, cost, profit)

eg EXPANDABILITY,2,9

indicates that the cost of including EXPANDABILITY is quite low (2) but that it carries the potential for high profits, through sale of expansions.

Table 12.2: Cost and Profit Margin of Features.

NO.	FEATURE	COST	PROFIT
1	GOOD BASIC	5	2
2	GRAPHICS	7	2
3	SOUND	6	2
4	A GOOD KEYBOARD	4	2
5	FUNCTION KEYS	1	5
6	A LARGE MEMORY	3	6
7	A TAPE INTERFACE	2	2
8	MACRODRIVES	2	4
9	DISCS	5	8
10	EXTENSIVE SOFTWARE	0	9
11	A CARTRIDGE PORT	1	6
12	A JOYSTICK PORT	1	7
13	AN ASSEMBLER	2	1
14	A CENTRONICS PORT	2	5
15	AN RS232 PORT	2	6
16	EXPANDABILITY	2	9
17	NETWORKING	3	4
18	A 16-BIT CPU	1	7
19	MULTITASKING	5	5
20	GOOD SERVICE	1	9

After each input the salesman considers the consequences of your requests. First of all he looks to see if your SPENDING on your requirements exceeds a certain proportion of your bank balance, and if so prints out one of a series of caustic comments on your credit-worthiness like:

THIS SPECIFICATION SEEMS TO BE  
EXCEEDING YOUR CREDIT LIMIT

He also looks at how much profit he is likely to make on the sale so far, and if this drops too low he will start to lose interest and come up with comments like:

I HAVE AN URGENT APPOINTMENT

or

WE CLOSE IN FIVE MINUTES

At the same time he will be more helpful with regard to which of the available computers will fit your requirements, using PICK\_COMPUTER which draws up a short list by comparing the rating given originally to this feature in the description of each computer with the value you put on it. The format for the descriptions (Table 12.3) is:

Table 12.3: Computer Feature Ratings.

NAME	FEATURES																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
JCN PC	7	8	8	9	8	8	8	0	9	9	7	7	0	7	6	8	8	9	9	9
KNACT SERIOUS	6	7	6	8	8	8	8	0	8	8	0	0	0	7	6	8	8	9	9	7
CLEAR SIN MT	9	9	9	7	7	8	8	9	9	6	7	7	0	7	6	7	9	9	9	1
ACHRON ILLUSION	8	7	6	6	0	3	7	0	5	5	0	0	6	0	0	4	1	0	0	2
BANANA IIE	3	5	2	5	0	4	6	0	3	0	3	5	0	0	6	7	0	0	0	4
SI ELITE	8	8	8	7	7	8	8	0	7	2	7	4	0	0	6	0	0	0	0	0
COLECTOVISION																				
CABBAGE	5	5	5	5	2	5	5	5	5	1	7	7	0	0	6	5	0	9	0	0
CANDY COLOURED																				
COMPUTER	7	6	4	2	0	2	7	0	4	9	8	7	0	0	6	3	0	0	0	6
COMANDEAR 64	2	8	9	7	7	6	5	0	6	9	6	7	0	0	2	2	0	0	0	6
ATRIA 600GT	1	8	8	5	0	2	5	0	7	7	7	7	0	0	6	6	0	0	0	5

(name, value of feature 1, value of feature 2, value of feature 3, etc)

The highest-rated machine will always be picked out first but, if possible, at least three machines (possibly with lower ratings) will be selected, and the final choice made from them. Either the highest or lowest cost computer (at random) will be selected for mention, for example:

IF YOU WANT A REAL ROLLS-ROYCE  
THEN JUST LOOK AT THE . . .

and

IF YOU ARE IN THE BUDGET MARKET  
THEN WHAT ABOUT THE . . .

If only one machine fits the bill the program will come up with:

YOUR ONLY OPTION IS THE . . .

#### Computer Salesman

```

10 SCREEN
20 TITLE
30 SET_UP
40 REPEAT QUESTION
50 PICK_QUESTION
60 IF FIND_slash THEN
70 LOOK_at
80 LOOK_and
90 END IF
100 IF FIND_ask THEN
110 JOIN_1
120 ELSE
130 JOIN_2
140 END IF
150 PRINT #3,PH$ & "?"
160 INPUT #0, IN$
170 IN$=" " & IN$
180 LD%=1
190 OF%=-1
200 FS%=1
210 NP%=0
220 RU%=0

```

```

230 M%=0
240 OM%=0
250 S1%=0
260 S2%=0
270 IF FIND_comma THEN
280 AND_OR_BUT
290 IN$=IN$(CM%+1 TO)
300 END IF
310 YES_PRESENT
320 NO_PRESENT
330 NT_PRESENT
340 DOUBLE_NEGATIVE
350 LIKES
360 DISLIKES
370 OBJECTS
380 ADVERBS
390 NEGATIVE_ADVERBS
400 ADJECTIVES
410 NEGATIVE_ADJECTIVES
420 CLS #1
430 CHEAP_EXPENSIVE
440 IF M%<1 THEN PRINT "PARDON, PLEASE
    EXCUSE ME BUT" : NEXT QUESTION
450 IF OM%>1 THEN PRINT "HANG ON - ONE
    THING AT A TIME" : NEXT QUESTION
460 RULE_UPDATE
470 COST_PROFIT
480 SPENDING
490 PICK_COMPUTER
500 Q%=Q%+1
510 IF Q%>19 THEN Q%=0
520 END REPEAT QUESTION
1000 Define PROCEDURE PICK_QUESTION
1010 PH%=RND(4 TO QP%)
1020 PH%=QP$(PH%)
1030 END Define PICK_QUESTION

2000 Define FuNction FIND_slash
2010 IS%="/" INSTR PH$
2020 RETURN IS%
2030 END Define FIND_slash

3000 Define PROCEDURE LOOK_at

```

```

3010 IF Q$(Q%,1)="Q" THEN
3020 PH$=PH$(1 TO IS%-1) & "ARE" & PH$
    (IS% TO)
3030 END IF
3040 END Define LOOK_at

4000 Define PROCEDURE LOOK_and
4010 IF Q$(Q%,1)="/" THEN
4020 PH$=PH$(1 TO IS%-1) & "IS" & PH$
    (IS% TO)
4030 END IF
4040 END Define LOOK_and

5000 Define FuNction FIND_ask
5010 IS%="/" INSTR PH$
5020 RETURN IS%
5030 END Define FIND_ask

6000 Define PROCEDURE JOIN_1
6010 PH$=PH$(1 TO IS%-2) & " " & Q$(Q%)(2
    TO LEN(Q$(Q%))) & PH$(IS%+1 TO)
6020 END Define JOIN_1

7000 Define PROCEDURE JOIN_2
7010 PH$=PH$ & " " & Q$(Q%)(2 TO LEN(Q$(Q%)))
7020 END Define JOIN_2

8000 Define FuNction FIND_comma
8010 CM%="," INSTR IN$
8020 RETURN CM%
8030 END Define FIND_comma

9000 Define PROCEDURE AND_OR_BUT
9010 IF FIND_AND + FIND_BUT THEN
9020 IF IN$(1 TO 3)="NO" THEN
9030 R(Q%)=((R(Q%)*3)-3)/3
9040 IC(Q%)=((IC(Q%)*3)-(CR(Q%)*3))/3
9050 IP(Q%)=((IP(Q%)*3)-(PR(Q%)*3))/3
9060 ELSE
9070 R(Q%)=R(Q%)+1
9080 IC(Q%)=((IC(Q%)*3)+(CR(Q%)*3))/3
9090 IP(Q%)=((IP(Q%)*3)+(PR(Q%)*3))/3
9100 END IF
9110 END IF
9120 END Define AND_OR_BUT

```

```

10000 DEFine FuNction FIND_AND
10010  S1%="AND" INSTR IN$
10020  RETURN S1%
10030 END DEFine FIND_AND

11000 DEFine FuNction FIND_BUT
11010  S2%="BUT" INSTR IN$
11020  RETURN S2%
11030 END DEFine FIND_BUT

12000 DEFine PROCedure YES_PRESENT
12010  ST%=1
12020  I1$=IN$
12030  REPeat YES
12040    I1$=I1$(ST% TO)
12050    SP%="YES" INSTR I1$
12060    IF SP%=0 THEN RETURN
12070    RU%=RU%+1
12080    LD%=1
12090    M%=1
12100    ST%=SP%+1
12110  END REPeat YES
12120 END DEFine YES_PRESENT

13000 DEFine PROCedure NO_PRESENT
13010  ST%=1
13020  I1$=IN$
13030  REPeat NO
13040    I1$=I1$(ST% TO)
13050    SP%="NO" INSTR I1$
13060    IF SP%=0 THEN RETURN
13070    LD%=-1
13080    M%=1
13090    ST%=SP%+1
13100    NP%=NP%+1
13110  END REPeat NO
13120 END DEFine NO_PRESENT

14000 DEFine PROCedure NT_PRESENT
14010  ST%=1
14020  I1$=IN$
14030  REPeat NT
14040    I1$=I1$(ST% TO)
14050    SP%="N'T" INSTR I1$

```

```

14060      IF SP%=0 THEN RETURN
14070      LD%=-1
14080      M%=1
14090      ST%=SP%+1
14100      NP%=NP%+1
14110  END REPeat NT
14120 END DEFine NT_PRESENT

15000 DEFine PROCedure DOUBLE_NEGATIVE
15010  IF NP%=0 THEN RETURN
15020  IF NP% MOD 2 THEN
15030    RU%=(RU%*3)-3)/3
15040    LD%=-1
15050  ELSE
15060    RU%=RU%+1
15070    LD%=1
15080  END IF
15090 END DEFine DOUBLE_NEGATIVE

16000 DEFine PROCedure LIKES
16010  FOR N=0 TO LI%
16020    SP%=LI$(N) INSTR IN$
16030    IF SP%>0 THEN
16040      IF IN$(SP%-1)=" " THEN LD%=LD%*1
        : M%-1
16050    END IF
16060  END FOR N
16070 END DEFine LIKES

17000 DEFine PROCedure DISLIKES
17010  FOR N=0 TO DL%
17020    SP%=DL$(N) INSTR IN$
17030    IF SP%>0 THEN
17040      IF IN$(SP%-1)=" " THEN LD%=LD%*-1
        : RU%=RU*-1 : M%=1
17050    END IF
17060  END FOR N
17070 END DEFine DISLIKES

18000 DEFine PROCedure OBJECTS
18010  FOR N=0 TO OB%
18020    SP%=OB$(N) INSTR IN$
18030    IF SP%>0 THEN

```



```

18040      IF IN$(SP%-1)=" " THEN
           RU%=((RU%*3)+(LD%*3))/3 : OF%=N :
           M%=1 : OM%=OM%+1
18050      END IF
18060      END FOR N
18070      END Define OBJECTS

19000      Define PROCedure ADVERBS
19010      FOR N=0 TO AV%
19020      SP%=AV$(N) INSTR IN$
19030      IF SP%>0 THEN
19040      IF IN$(SP%-1)=" " THEN
           RU%=((RU%*3)+(LD%*3))/3 : M%=1
19050      END IF
19060      END FOR N
19070      END Define ADVERBS

20000      Define PROCedure NEGATIVE_ADVERBS
20010      FOR N=0 TO NV%
20020      SP%=NV$(N) INSTR IN$
20030      IF SP%>0 THEN
20040      IF IN$(SP%-1)=" " THEN LD%=LD%*-1
           : RU%=((RU%*3)+(LD%*3))/3 : M%=1
20050      END IF
20060      END FOR N
20070      END Define NEGATIVE_ADVERBS

21000      Define PROCedure ADJECTIVES
21010      FOR N=0 TO AJ%
21020      SP%=AJ$(N) INSTR IN$
21030      IF SP%>0 THEN
21040      IF IN$(SP%-1)=" " THEN
           RU%=((RU%*3)+(LD%*3))/3 : M%=1
21050      END IF
21060      END FOR N
21070      END Define ADJECTIVES

22000      Define PROCedure NEGATIVE_ADJECTIVES
22010      FOR N=0 TO NJ%
22020      SP%=NJ$(N) INSTR IN$
22030      IF SP%>0 THEN
22040      IF IN$(SP%-1)=" " THEN LD%=LD%*-1
           : RU%=((RU%*3)+(LD%*3))/3 : M%=1

```

```

22050      END IF
22060      END FOR N
22070      END Define NEGATIVE_ADJECTIVES

23000      Define PROCedure CHEAP_EXPENSIVE
23010      FOR N=0 TO HM%
23020      SP%=HM$(N) INSTR IN$
23030      IF SP%>0 THEN
23040      IF IN$(SP%-1)=" " THEN
           XX%=N
23060      IF XX%<2 THEN PRINT "CHEAP AND
           NASTY"
           IF XX%>=2 THEN PRINT "RATHER
           EXPENSIVE"
23070      END IF
23080      END IF
23090      END FOR N
23100      END FOR N
23110      END Define CHEAP_EXPENSIVE

24000      Define PROCedure RULE_UPDATE
24010      IF OF%>-1 THEN
24020      R(OF%)=((R(OF%)*3)+(RU%*3))/3
24030      IC(OF%)=((IC(OF%)*3)+((CR(OF%)*RU%
           *3))/3
24040      IP(OF%)=((IP(OF%)*3)+((PR(OF%)*RU%
           *3))/3
24050      ELSE
24060      R(Q%)=((R(Q%)*3)+(RU%*3))/3
24070      IC(Q%)=((IC(Q%)*3)+((CR(Q%)*RU%
           *3))/3
24080      IP(Q%)=((IP(Q%)*3)+((PR(Q%)*RU%
           *3))/3
24090      END IF
24100      CLS #2
24110      PRINT #2,"DESIRE"
24120      FOR N=0 TO R%
24130      AT #2,N*3+15,0 : PRINT#2, R(N)
24140      END FOR N
24150      PRINT#2,"COST"
24160      FOR N=0 TO R%
24170      AT #2,N*3+15,1 : PRINT#2, IC(N)
24180      END FOR N
24190      PRINT#2,"PROFIT"
24200      FOR N=0 TO R%

```

```

24210      AT #2,N#3+15,2 : PRINT#2, IP(N)
24220      END FOR N
24230 END DEFine RULE_UPDATE

25000 DEFine PROCedure COST_PROFIT
25010      FOR N=0 TO 0B%
25020          TC%=((TC%*3)+(IC(N)*3))/3
25030          TP%=((TP%*3)+(IP(N)*3))/3
25040      END FOR N
25050      PAPER #2,0 : INK #2,7 : CSIZE #2,1,0
25060      PRINT #2,"      TOTAL COST ";TC%;"      TOTAL
      PROFIT ";TP%;"      BANK BALANCE ";BB%;
25070      PAPER #2,4 : INK #2,0 : CSIZE #2,0,0
25080 END DEFine COST_PROFIT

26000 DEFine PROCedure SPENDING
26010      IF TP%<Q%*5 THEN TX%=RND(EX%) : INK
      #1,4 : PRINT \EX%(TX%) : INK #1,0
26020      IF TC%>BB%/(Q%+1) THEN PT%=RND(CS%) :
      INK #1,2 : PRINT \CS%(PT%) : INK #1,0
26030      TC%=0
26040      TP%=0
26050 END DEFine SPENDING

27000 DEFine PROCedure PICK_COMPUTER
27010      FOR X=9 TO 0 STEP -1
27020          PO$=""
27030          FOR N=0 TO CO%
27040              IF ((FE(N,Q%)*3)-(R(Q%)*3))>X THEN
                  PO$=PO$ & N : M%=N
27050          END FOR N
27060          IF LEN(PO$)<3 THEN END FOR X
27070          TS%=0
27080          BS%=10
27090          FOR CH=0 TO LEN(PO$)-1
27100              NC%=PO$(CH+1)
27110              IF C(NC%)>=TS% THEN TS%=C(NC%)
                  : HI%=NC%
27120              IF C(NC%)<=BS% THEN BS%=C(NC%)
                  : LO%=NC%
27130          END FOR CH
27140          IF HI%=LO% THEN
27150              PRINT #1,"YOUR ONLY OPTION IS
      THE"

```

```

27160              CSIZE #1,2,1 : PRINT #1," ***
      ** ";CO$(HI%);" ***** "; :
      CSIZE #1,2,0
27170          RETURN
27180      END IF
27190      FI%=CO$(HI%)
27200      LA%=CO$(LO%)
27210      SE%=RND(1 TO 2)
27220      SL%=RND(2)
27230      IF SE%<>2 THEN
27240          PRINT #1,HI$(SL%) : CSIZE
      #1,2,1 : PRINT #1," ***** "
      ;FI%;" *****"; CSIZE #1,2,0
27250      ELSE
27260          PRINT #1,LO$(SL%) : CSIZE
      #1,2,1 : PRINT #1," ***** "
      ;LA%;" *****"; CSIZE #1,2,0
27270      END IF
27280 END DEFine PICK_COMPUTER

28000 DEFine PROCedure SCREEN
28010      MODE 4
28020      WINDOW #0,470,40,25,215
28030      BORDER #0,5,4
28040      PAPER #0,0
28050      INK #0,7
28060      CSIZE #0,2,0
28070      CLS #0
28080      WINDOW #1,470,105,25,90
28090      BORDER #1,5,4
28100      PAPER #1,7
28110      INK #1,0
28120      CSIZE #1,2,0
28130      CLS #1
28140      WINDOW #2,470,50,25,15
28150      BORDER #2,5,4
28160      PAPER #2,4
28170      INK #2,0
28180      CSIZE #2,0,0
28190      CLS #2
28200      OPEN #3,SCR_470X20A25X195
28210      BORDER #3,5,4
28220      PAPER #3,7
28230      INK #3,0

```

```

28240 CSIZE #3,2,0
28250 CLS #3
28260 OPEN #4,SCR_470X25A25X63
28270 BORDER #4,2,2
28280 PAPER #4,2
28290 INK #4,7
28300 CSIZE #4,2,1
28310 CLS #4
28320 END Define SCREEN

```

```

29000 Define PROCedure TITLE
29010 PRINT #4," $$$$ MULTIMEGA MICROSTORE
        $$$$";
29020 END Define TITLE

```

```

30000 Define PROCedure SET_UP
30010 RESTORE
30020 QP%=5
30030 Q%=19
30040 R%=Q%
30050 OB%=Q%
30060 AJ%=7
30070 AV%=4
30080 LI%=3
30090 DL%=3
30100 NJ%=8
30110 NV%=2
30120 HM%=3
30130 BB%=100
30140 CO%=9
30150 FE%=19
30160 CT%=9
30170 HI%=2
30180 LO%=2
30190 CS%=2
30200 EX%=2
30210 TC%=0
30220 TP%=0
30230 DIM OB*(OB%,10)
30240 DIM AJ*(AJ%,6)
30250 DIM NJ*(NJ%,7)
30260 DIM AV*(AV%,6)
30270 DIM NV*(NV%,6)

```

```

30280 DIM LI*(LI%,7)
30290 DIM DL*(DL%,7)
30300 DIM Q*(Q%,20)
30310 DIM QP*(QP%,16)
30320 DIM HM*(HM%,20)
30330 DIM R*(R%)
30340 DIM CR*(Q%)
30350 DIM PR*(Q%)
30360 DIM IC*(Q%)
30370 DIM IP*(Q%)
30380 DIM CO*(CO%,30)
30390 DIM FE*(CO%,FE%)
30400 DIM DF*(CO%,FE%)
30410 DIM C*(CT%)
30420 DIM CS*(CS%,100)
30430 DIM EX*(EX%,100)
30440 DIM HI*(HI%,100)
30450 DIM LO*(LO%,100)
30460 DATA "BASIC","GRAPHIC","SOUND",
        "KEYBOARD","FUNCTION","MEMORY",
        "TAPE","MACRODRIVE","DISC"
30470 DATA "SOFTWARE","CARTRIDGE",
        "JOYSTICK","ASSEMBL","CENTRONIC",
        "RS232","EXPAND"
30480 DATA "NETWORK","16-BIT","MULTITASK",
        "SERVICE"
30490 DATA "GOOD","EXCEL","SUPER","MAGNIF",
        "FIRST","FAST","ESSENT","LOT"
30500 DATA "BAD","RUBBISH","POOR","SLOW",
        "INEFFIC","FEW","WORS","LEAST","LESS"
30510 DATA "REAL","VERY","OFTEN","NECESS",
        "TRU"
30520 DATA "NEVER","UNNECES","INFREQ"
30530 DATA "WANT","LIKE","NEED","REQUIRE"
30540 DATA "HATE","DISLIKE","LOATHE","DETEST"
30550 DATA "&GOOD BASIC",5,2,"&GRAPHICS",7,2,
        "&SOUND",6,2,"&A GOOD KEYBOARD",4,2
30560 DATA "&FUNCTION KEYS",1,5,"&A LARGE
        MEMORY",3,6,"&A TAPE INTERFACE",2,2
30570 DATA "&MACRODRIVES",2,4,"&DISCS",5,8,
        "&EXTENSIVE SOFTWARE",0,9
30580 DATA "&A CARTRIDGE PORT",1,6,"&A
        JOYSTICK PORT",1,7,"&AN ASSEMBLER",2,1

```

```

30590 DATA "&A CENTRONICS PORT",2,5,"&AN RS232
      PORT",2,6,"&EXPANDABILITY",2,9,
      "&NETWORKING",3,4
30600 DATA "&A 16-BIT CPU",1,7,"&MULTITASKING"
      ,5,5,"&GOOD SERVICE",1,9
30610 DATA "WOULD YOU LIKE","WHAT ABOUT","HOW
      ABOUT","DO YOU WANT","DO YOU REQUIRE",
      "/* IMPORTANT"
30620 DATA "CHEAP","INEXPENSIVE"
30630 DATA "DEAR","EXPENSIVE"
30640 DATA "JCN PC",7,8,8,9,8,8,8,0,9,9,7,7,0
      ,7,6,8,8,9,9,9
30650 DATA "KNACT SERIOUS",6,7,6,8,8,8,8,0,8,
      8,0,0,0,7,6,8,8,9,9,7
30660 DATA "CLEAR SIN MT",9,9,9,7,7,8,8,9,9,6,7
      ,7,0,7,6,7,9,9,9,1
30670 DATA "ACHRON ILLUSION",8,7,6,6,0,3,7,0,
      5,5,0,0,6,0,0,4,1,0,0,2
30680 DATA "BANANA IIE",3,5,2,5,0,4,6,0,3,0,3
      ,5,0,0,6,7,0,0,0,4
30690 DATA "SI ELITE",8,8,8,7,7,8,8,0,7,2,7,
      4,0,0,6,0,0,0,0,0
30700 DATA "COLECTOVISION CABBAGE",5,5,5,5,
      2,5,5,5,5,1,7,7,0,0,6,5,0,9,0,0
30710 DATA "CANDY COLOURED COMPUTER",7,6,4,2,
      0,2,7,0,4,9,8,7,0,0,6,3,0,0,0,6
30720 DATA "COMANDEAR 64",2,8,9,7,7,6,5,0,6
      ,9,6,7,0,0,2,2,0,0,0,6
30730 DATA "ATRIA 600GT",1,8,8,5,0,2,5,0,7,7,
      7,7,0,0,6,6,0,0,0,5
30740 DATA 10,9,8,7,6,5,4,3,2,1
30750 DATA "I THINK YOU ARE GETTING OUT OF
      YOUR PRICE RANGE"
30760 DATA "THIS SPECIFICATION SEEMS TO BE
      EXCEEDING YOUR CREDIT LIMIT"
30770 DATA "I DON'T THINK THAT YOU CAN AFFORD
      SUCH LUXURIES"
30780 DATA "EXCUSE ME, I CAN HEAR THE PHONE
      RINGING"
30790 DATA "I HAVE AN URGENT APPOINTMENT"
30800 DATA "WE CLOSE IN FIVE MINUTES"
30810 DATA "IF YOU ARE IN THE BUDGET MARKET
      THEN WHAT ABOUT THE ","AN INEXPENSIVE
      CHOICE IS THE"

```

```

30820 DATA "YOU GET GOOD VALUE FOR MONEY WITH
      THE"
30830 DATA "IF YOU WANT A FIRST CLASS PRODUCT
      THEN YOU MUST TRY THE"
30840 DATA "FOR STATE OF THE ART TECHNOLOGY
      YOU CAN'T BEAT THE"
30850 DATA "IF YOU WANT A ROLLS ROYCE THEN
      JUST LOOK AT THE"
30860   FOR N=0 TO OB%
30870     READ OB$(N)
30880   END FOR N
30890   FOR N=0 TO AJ%
30900     READ AJ$(N)
30910   END FOR N
30920   FOR N=0 TO NJ%
30930     READ NJ$(N)
30940   END FOR N
30950   FOR N=0 TO AV%
30960     READ AV$(N)
30970   END FOR N
30980   FOR N=0 TO NV%
30990     READ NV$(N)
31000   END FOR N
31010   FOR N=0 TO LI%
31020     READ LI$(N)
31030   END FOR N
31040   FOR N=0 TO DL%
31050     READ DL$(N)
31060   END FOR N
31070   FOR N=0 TO Q%
31080     READ Q$(N)
31090     READ CR(N)
31100     READ PR(N)
31110   END FOR N
31120   FOR N=0 TO QP%
31130     READ QP$(N)
31140   END FOR N
31150   FOR N=0 TO HM%
31160     READ HM$(N)
31170   END FOR N
31180   FOR N=0 TO CO%
31190     READ CO$(N)
31200   FOR M=0 TO FE%
31210     READ FE(N,M)

```

```
31220      END FOR M
31230      END FOR N
31240      FOR N=0 TO CT%
31250          READ C(N)
31260      END FOR N
31270      FOR N=0 TO CS%
31280          READ CS*(N)
31290      END FOR N
31300      FOR N=0 TO EX%
31310          READ EX*(N)
31320      END FOR N
31330      FOR N=0 TO LO%
31340          READ LO*(N)
31350      END FOR N
31360      FOR N=0 TO HI%
31370          READ HI*(N)
31380      END FOR N
31390      Q%=0
31400 END DEFine SET_UP

32000 DEFine PROCedure XX
32010  WINDOW #2,470,240,25,15
32020  PAPER #2,7
32030  INK #2,0
32040  CLS #2
32050 END DEFine XX
```

### **The rest is up to you**

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